NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

WILL THE LOGISTICS MANAGEMENT DECISION SUPPORT SYSTEM MEET THE INFORMATION AND DECISION PROCESS REQUIREMENTS OF ITS USERS?

by

Mark W. Krause
Ellen M. Evanoff

September 1999

Co-Advisors: Donald R. Eaton
William J. Haga

Approved for public release; distribution is unlimited.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1999	Master's Thesis

4. TITLE AND SUBTITLE : Will the Logistics Management Decision Support System Meet the Information and Decision Process Requirements of Its Users?

5. FUNDING NUMBERS

6. AUTHOR(S)
Krause, Mark W. and Evanoff, Ellen M.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)*

The development of the Logistics Management Decision Support System (LMDSS) by the Naval Air Systems Command (NAVAIR) has been on going since 1991. Originally conceived as a strategic Decision Support System (DSS), LMDSS has instead evolved into a Web portal for data analysts to access NAVAIR's Aviation Maintenance and Material Management (AV-3M) data. LMDSS is more accurately described as a Web-based, Management Information System (MIS) than as a DSS.

This research examines the information needs and decision process requirements of LMDSS users. Focus groups, interviews, and a Web-based survey were conducted to collect decision support and data requirements from Fleet customers. User perceptions, feedback, and recommendations to improve LMDSS are described and analyzed. Historical insights into the development history of LMDSS are introduced as a lessons learned for future NAVAIR software teams.

Problems identified by users are presented followed by specific recommendations for solutions. A protype model developed for this thesis is found in the appendices as an example of how a modeling capability could enhance the ability of LMDSS to better support strategic, unstructured decisions.. Recommendations are provided for future research.

14. SUBJECT TERMS
Logistics Management Decision Support System, LMDSS, NALDA, Decision Support Systems, Software Development

15. NUMBER OF PAGES
171

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFI- CATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

Approved for public release; distribution is unlimited

WILL THE LOGISTICS MANAGEMENT DECISION SUPPORT SYSTEM MEET THE INFORMATION AND DECISION PROCESS REQUIREMENTS OF ITS USERS?

Mark W. Krause
Commander, United States Naval Reserve
B.S., United States Naval Academy, 1981
M.Ed., University of North Florida, 1989

Ellen M. Evanoff
Lieutenant Commander, United States Navy
A.B., The University of Chicago, 1987

Submitted in partial fulfillment of the
Requirements for the degree of

MASTER OF SCIENCE IN INFORMATION TECHNOLOGY MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
September 1999

Authors: ______________________
Mark W. Krause

____
Ellen M. Evanoff

Approved by: ______________________
Donald R. Eaton, Co-Advisor

____
William J. Haga, Co-Advisor

____
Dan Boger, Chairman
Information Systems Academic Group

ABSTRACT

The development of the Logistics Management Decision Support System (LMDSS) by the Naval Air Systems Command (NAVAIR) has been on going since 1991. Originally conceived as a strategic Decision Support System (DSS), LMDSS has instead evolved into a Web portal for data analysts to access NAVAIR's Aviation Maintenance and Material Management (AV-3M) data. LMDSS is more accurately described as a Web-based, Management Information System (MIS) than as a DSS.

This research examines the information needs and decision process requirements of LMDSS users. Focus groups, interviews, and a Web-based survey were conducted to collect decision support and data requirements from Fleet customers. User perceptions, feedback, and recommendations to improve LMDSS are described and analyzed. Historical insights into the development history of LMDSS are introduced as a lessons learned for future NAVAIR software teams.

Problems identified by users are presented followed by specific recommendations for solutions. A protype model developed for this thesis is found in the appendices as an example of how a modeling capability could enhance the ability of LMDSS to better support strategic, unstructured decisions.. Recommendations are provided for future research.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ADM - Admiral

AEMS - Aircraft Engine Management System

AIRRS - Aircraft Inventory and Readiness Reporting System

AIMD - Aviation Intermediate Maintenance Depot

AIS - Automated Information System

AIX - Advanced Interactive Executive

AMSR - Aviation Maintenance Supply Readiness

ANOVA - Analysis of Variance

APB - Acquisition Program Baseline

APML - Assistant Program Manager, Logistics

ASO - Aviation Supply Office

AV-3M - Aviation Maintenance and Material Management

CASE - Computer Aided Software Engineering

CBIS - Computer Based Information System

CESN - CNET's Electronic Schoolhouse Network

CGI - Common Graphics Interface

CIO - Chief Information Officer

CM - Configuration Management

CNAP - Commander, Naval Air Force Pacific

CNET - Chief of Naval Education and Training

COMNAVRESFOR - Commander, Naval Reserve Force

COMNAVAIRRESFOR- Commander, Naval Air Reserve Force

COMNAVAIRPAC - Commander, Naval Air Force Pacific

COMNAVAIRSYSCOM - Commander, Naval Air Systems Command

COE - Common Operating Environment

COL - Colonel

COTS - Common off the shelf

DDM - Dialog Data Model

DII - Defense Information Infrastructure

DISA - Defense Information System Agency

DoD - Department of Defense

DSS - Decision Support System

DV- Dependent Variable

ESM - Evaluation and Selection of Alternative Modules

FOJ - Fleet Originated Job

GCSS - Global Combat Support System

GOLD - Government Online Data System

GS - General Schedule

GUI - Graphics User Interface

HTML - HyperText Markup Language

ILS - Integrated Logistics Support

IT-21 - Information Technology for the 21st Century

IV - Independent Variable

IWSDB - Integrated Weapons System Database

JMCIS - Joint Maritime Command Information System

K-W - Kruskal Wallis

LCDR - Lieutenant Commander

LMDSS - Logistics Management Decision Support System

LOC - Lines of Code

MAF - Maintenance Action Form

MAIS - Major Acquisition of Information Systems

MBMS - Model Based Management System

MIS - Management Information System

MS - Microsoft

MV - Moderating Variable

NADEP - Naval Depot

NALCOMIS - Naval Aviation Logistics Command Management Information System

NALDA - Naval Aviation Logistics Data and Analysis

NAS - Naval Air Station

NAVAIR - Naval Air Systems Command

NAVICP - Naval Inventory Control Point

NAWC - Naval Air Warfare Center

NDLMS - Naval Depot Logistics Management System

NSLC - Naval Sea Logistics Command

O&M - Operations and Maintenance

PERL - Practical Extraction and Report Language

POM - Program Objective Memorandum

PMA - Program Manager, Air

P-3 - Maritime Patrol Aircraft

QA - Quality Assurance

RDBMS - Relational Data Base Management System

RFI - Ready For Installation

RISC - Reduced Instruction Set Computing

SALTS - Streamline Alternative Logistics Transmission System

SBA - Small Business Administration

SOW - Statement of Work

SPAWARS - Space Warfare Systems

SQL - Structured Query Language

SPR - Software Productivity Research

TCP/IP - Transmission Control Protocol/ Internet Protocol

TMS - Type Model Series

UNIX - Mult ICS

USN - United States Navy

USNR - United States Naval Reserve

USA - United States Army

WAN - Wide Area Network

WSM - Weapons System Manager

WWW - World Wide Web

Y2K - Year 2000

ACKNOWLEDGMENT

The authors would like to acknowledge the financial support of NAVAIR, Code 3.6.2, for sponsoring the November 1998 thesis trip to NAS Patuxent River. They wish to extend their appreciation to the entire NAVAIR LMDSS team for their patience and assistance. A special thanks goes to Mr. John Mishler, Mr. Doug Jahn, Mr. Joe Joseph, Mr. Wally Moore, Mr. Duane Bishop, Mr. Chuck Gauch, Mr. Monty Jones and LCDR Mike Kelly, USN.

The authors would like to thank the following professors: COL Dave Matthews, USA (Retired) for his acquisition expertise, Dr. Hemant Bhargava for his Decision Support System expertise and Dr. John Osmundson for his software development knowledge and his assistance in building the SH-60B Logistics Model.

The authors also wish to thank ADM Donald Eaton, USN (Retired) and Dr. William Haga for their unending guidance and insightful commentary.

Most importantly, the authors would like to thank their spouses, Linda and Tom, for putting up with us when the going got rough. (Especially when survey respondents telephoned routinely at three in the morning with email addresses and when the computer ate portions of this thesis for a midnight snack). Your patience and support made this project possible.

I. INTRODUCTION

A. BACKGROUND

The first effort toward building a Decision Support System (DSS) for program managers at the Naval Air Systems Command (NAVAIR) began in 1991. NAVAIR's Program Managers, Air (PMAs) and Assistant Program Managers, Logistics (APMLs) needed a tool to help them investigate alternatives and make optimal, unstructured decisions in their efforts to reduce life cycle program costs while maintaining readiness. In 1994, such a tool was completed and named the Logistics Management Decision Support System (LMDSS).

When Rear Admiral Donald Eaton (NAVAIR 4.0) and others were briefed on the LMDSS program in 1994, many were excited by its potential. One APML even reported attaining a $42 million cost avoidance when LMDSS was used to identify and solve a problem in the F-14 avionics system. It appeared that LMDSS might just be the tool PMAs needed to better manage the life cycle support costs of their programs as harsh budget cuts loomed on the horizon.

Years later, as the Logistics Program Department Head at the Naval Postgraduate School, Rear Admiral (retired) Donald Eaton wondered whatever became of the LMDSS program that showed so much promise back in 1994. One of the goals of this thesis is to find out what happened to the LMDSS program. Does LMDSS currently meet the requirements of its users?

B. OBJECTIVES

The primary objective of this research is to investigate the information needs and decision process requirements of current LMDSS users. A secondary objective is to document how and why LMDSS took eight years to transition from a strategic level DSS to a Web based Relational Database Management System (RDBMS) interface for Fleet

data analysts at all levels. A final goal is to provide our sponsor, NAVAIR 3.6.2, with user feedback and research results to assist in the management of the LMDSS program.

C. RESEARCH QUESTIONS

The primary research question is: "Does LMDSS meet user requirements?" Other major research questions are:

- How can LMDSS be improved to better meet managerial needs?
- What are the significant decisions users would like LMDSS to support?
- How has LMDSS been funded?
- How can NAVAIR improve the LMDSS program?
- What can future software developers learn from studying the LMDSS project?
- What are the key attitudes and opinions of LMDSS users?

D. ORGANIZATION OF THE THESIS

This study documents some of the key events that occurred during the eight-year effort to develop LMDSS and examines whether or not LMDSS currently meets the requirements of its users. Chapter II is a review of previous LMDSS research, DSS literature, and results from current software development research. Chapter III reviews the history of the LMDSS project and discusses how it has been funded. Chapter IV documents a detailed description of the research methodology used in this thesis. Chapter V reports the research findings. Chapter VI presents an analysis of the findings and provides answers to the above research questions. Chapter VII provides a continued discussion of what the research results mean with conclusions and corresponding recommendations. A prototype model is presented in the appendix section as an example to the reader of how modeling can assist managers in making strategic, unstructured decisions.

II. LITERATURE REVIEW

A. PREVIOUS LMDSS RESEARCH

1. LMDSS Overview

The LMDSS concept was first introduced by the Naval Air Systems Command (NAVAIR) and the Naval Inventory Control Point (NAVICP), formally called the Aviation Supply Office (ASO), in 1991. The concept involved the development of a decision support system (DSS) to assist NAVAIR logistics and weapon system managers in reducing the life cycle support costs of aviation systems while maintaining readiness. Although the LMDSS application was completed, delivered, and operational for a short period in 1994, it was placed back into development to be restructured as a World Wide Web (WWW) based tool. As of the summer of 1999, LMDSS is still considered a prototype rather than a fully functional software application.

The only published research that specifically addresses the LMDSS application was completed by Moore and Snyder (1998) at the Naval Postgraduate School. They assessed the capability of LMDSS to meet the information requirements of NAVAIR's logistics managers. They also gauged whether the LMDSS prototype's capabilities satisfied the criteria of a DSS.

LMDSS is unusual because of the time it has been under development (over 8 years). As a result, we chose to expand the focus of research to include software development and acquisition issues in addition to user requirements. The goal is to help explain how LMDSS grew from a three-year project to a seemingly endless software development effort.

2. LMDSS Research Findings

Moore and Snyder (1998) concluded that:

- Because of its lack of modeling and sensitivity analysis, LMDSS is not a DSS. It is actually a relational database management system (RDBMS) interface that improves data accessibility.

- APMLs are only one of many potential user groups of LMDSS.
- LMDSS meets the requirements of surveyed logistics managers to support Affordable Readiness initiatives.
- Lack of modeling, graphics, and sensitivity analysis capabilities limits the identification, analysis, and comparison of Affordable Readiness initiatives using LMDSS.
- Data quality is both a real and perceived problem.
- The environment in which aviation program management decisions are made limits the effectiveness of LMDSS in measurably reducing life-cycle costs.

a) Research Weaknesses

Moore and Snyder's (1998) research targeted NAVAIR's APMLs as the primary users of LMDSS. Survey results from the nine APMLs contacted revealed only one respondent had personally used LMDSS. Their interviews revealed each of the APML program offices had its own unique strategy for accomplishing logistics and maintenance data analysis and collection. Some offices hired civilian contractors while others used various mixtures of in-house personnel and personnel assigned to lower echelon commands. They discovered data analysts rather than APMLs and PMAs were the actual users of LMDSS. Although LMDSS was originally designed to support PMAs and APMLs, its use has been delegated to lower level analysts. As a result, the LMDSS prototype has evolved from a PMA/APML decision tool to a RDBMS interface for Fleet data analysts. The requirements identified by the nine APMLs in Moore and Snyder's thesis are not representative of the needs of the larger, more varied population of over 800 LMDSS users.

The fact that LMDSS is still in the prototype phase and thus not widely used was mentioned as a significant research constraint (Moore and Snyder, 1998). Although LMDSS was scheduled to be operational by the summer of 1998, it was still undergoing quality assurance testing as of the summer of 1999. The constraints posed

when querying users about a prototype software tool that was not fully operational continue to be a problem for researchers.

b) Research Strengths

Moore and Snyder's (1998) thesis work reiterated how important it is for NAVAIR's PMAs to make smart decisions concerning life cycle support costs. The data collected showed that PMAs require more than a measuring tool to display costs. To make optimal decisions, PMAs and APMLs need the ability to test alternative courses of action to see how controllable and uncontrollable variables affect life-cycle costs and readiness. According to the APMLs, a fully functional DSS is still needed at the PMA and APML levels to make such decisions.

Previous research verified that LMDSS could not be classified as a DSS due to its inability to support modeling, graphics, and sensitivity analysis. Such limitations significantly degrade LMDSS's usefulness as an effective decision support tool for the PMAs and APMLs. One APML that Moore and Snyder interviewed stated,

> LMDSS is good at "big picture" and indicating "where to go look" but falls short of communicating details with ease or indicating "why" a system measurement is as it is..."LMDSS can help answer the what, but it can't help me with the why or the how." (Moore and Snyder, 1998, p. 86)

Moore and Snyder (1998) identified problem areas in the LMDSS environment that significantly degraded its effectiveness. Data quality issues, difficulties with depot cost data, and the need for users to understand the origin and derivation of data to fully utilize and trust LMDSS were noteworthy findings. It was noted that the environment of a typical PMA did not encourage or reward risk taking and creativity when considering life cycle costs. They wrote,

> The current environment encourages short-term decisions that compromise life-cycle decisions. The LMDSS can help identify and justify decisions to reduce life-cycle costs, but other factors are driving up these same costs. (Moore and Snyder, 1998, p. 93)

Instances where NAVAIR failed to communicate adequately with LMDSS users were also mentioned as potential problems. An example was the LMDSS web site's failure to clearly identify itself as a prototype site with only a partial database. This caused numerous misunderstandings at the user level. Such communication errors directly affected user perceptions about LMDSS's relevancy and led to a lack of acceptance and trust. (Moore and Snyder, 1998)

3. Identification of LMDSS Users

Moore and Snyder (1998) identified only one APML who was an actual LMDSS user. Most of the real users were found to be military and civilian data analysts at all levels within the Fleet. Much of the earlier DSS literature suggested the use of DSS might be more appropriate at only the higher levels of management. This was the view of those who originally developed LMDSS back in 1991. More recent DSS literature now claims the use of a DSS is appropriate at any management level. (Ariav and Ginsberg, 1985)

While much of the literature emphasizes DSS use by top management, in reality, middle management and professional staffers are often the real hands-on users of a DSS (Sprague, 1996).

> This does not mean that DSS is not used by top management. Rather, what often happens is that senior executives request information from a staff assistant who uses a DSS to obtain information. (Sprague, 1996, p. 103)

This finding appears to confirm what Moore and Snyder uncovered in their thesis. The PMAs and APMLs contacted by them admitted delegating the use of the LMDSS application to lower level analysts. This delegation provides some insight into how LMDSS transitioned from a strategic level decision tool to an analysis tool for Fleet data analysts.

One study conducted by Snead and Harrell discussed the gap between the capabilities of sophisticated computer-based information systems (CBIS) and the extent

they are used by managers. Their conclusions emphasized the important role a manager's expectations play in whether or not he accepts and uses a CBIS. A strategy that includes more extensive manager involvement and training to support the use of a CBIS was strongly recommended. The study suggests more aggressive training and close user involvement may be the key to getting NAVAIR's logistics and maintenance managers to accept and use LMDSS when it becomes fully operational. (Snead and Harrell, 1994)

A typical DSS user has much more latitude to ignore or circumvent the system than users of other more traditional CBIS. Research emphasizes how important it is for a DSS to earn the allegiance of its users by being valuable and convenient. (Sprague, 1980) Little (1970) called for DSSs to be simple, robust, easy to control and adaptive in order gain management support.

B. DECISION SUPPORT SYSTEM LITERATURE

On NAVAIR's web site, the LMDSS application is presented as a DSS which integrates data from maintenance, flight, cost, and material data bases into a structured and repeatable decision making process. In numerous NAVAIR briefs and plans, LMDSS is shown as Naval Aviation Logistics Data and Analysis (NALDA) II's primary analysis tool for historical Aviation Maintenance and Material Management (AV3M) data within NAVAIR's Integrated Weapons Systems Database (IWSDB). (NAVAIR, 1999)

To avoid misunderstandings when discussing a DSS, it is important to review the basic DSS definitions and terms provided by the literature.

1. What is a DSS?

An accepted definition of a DSS is one provided by Bhargava, Krishman, and Whinston (1994, p. 2):

> Traditional decision support systems (DSS) support individuals making *semi-structured decisions* in which mathematical (or other formal) models are used for the structured parts, leaving the decision maker to exercise judgement in handling the unstructured parts. Focusing on the choice-related tasks, DSS facilitate the use of formal modeling techniques in making complex decisions. Among the benefits claimed for these systems is that they facilitate the investigation of more alternatives, and support *ad hoc* query and analysis.

Another definition defines a DSS as a computer-based information system, which provides interactive information support to managers making semi-structured and unstructured decisions. A DSS supports managers by using, (1) analytical models, (2) specialized databases, (3) a decision-maker's own insights and judgements, and (4) an interactive, computer-based modeling process. (O'Brian, 1993)

Some terms in the above DSS definitions need to be clarified. An ***ad hoc*** query is a unique, situation-specific, unscheduled request for information. A ***structured*** decision occurs in situations where the procedures to follow in making a decision can be predicted and specified in advance. Often, the outcome of structured decisions can be predicted with relative certainty. An ***unstructured*** decision involves situations where it is not possible to know in advance what procedures to follow. Unstructured decisions involve too many random events, unknown variables, and hidden relationships to be able to follow any preset rules or checklists. A ***semi-structured*** decision is one where some of the decision procedures can be pre-specified, but not to an extent where it can lead to a definite decision. (O'Brian, 1993)

Currently the LMDSS application can support structured decisions and ad hoc queries, but is unable to assist with unstructured or semi-structured decisions due to the absence of modeling and sensitivity analysis.

2. What is the Decision-Making Process?

A classic model of a manager's decision process is depicted by Herbert Simon, a leader in the field of decision theory, who presented decision-making as consisting of

three phases: intelligence, design, and choice. The intelligence phase involves detecting problems, collecting problem data, and analysis of the environment. The design phase includes setting criteria and objectives, creating alternatives, and evaluating the outcome. The choice phase consists of determining the outcome of selected alternatives and selecting the desired outcome consistent with the decision objectives. Simon's work is important because it built the theoretical foundation still used by software engineers to build DSSs. (Simon, 1977)

Steven Alter added a fourth phase to Simon's model calling it the implementation phase. This phase involved the process of putting a manager's decision into effect. It included building a consensus to support the decision, explaining the decision to the right people, and fostering the commitment to follow through with the decision. Alter's research into this implementation phase revealed a DSS's greatest impact was not in aiding the decision-making process but with explaining and justifying decisions already made. (Alter, 1980)

3. Why do PMAs and APMLs need a DSS?

Most researchers agree that managers are not completely rational decision-makers. An ideal rational decision-maker performs all three phases of Simon's model flawlessly. Such a decision-maker ensures all information is gathered and interpreted in an unbiased manner. He identifies all practical alternatives and evaluates them using unambiguous criteria. He then selects the best alternative based on a consistent and explicit set of weightings and trade-offs. (Alter, 1992)

In the real world, however, managers don't have time to collect all decision-related information and fully explore all feasible alternatives. Clear, focused objectives and criteria are often not completely defined with more weight placed on intangible information. Alter (1992) identified eight common managerial decision-making flaws:

- Poor Framing: Allowing a decision to be influenced excessively by the language used in describing the decision
- Recency Effects: Giving undue weight to the most recent information

- Primacy Effects: Giving undue weight to the first information received
- Poor Probability Estimation: Overestimating the probability of familiar or dramatic events; underestimating the probably of negative events
- Overconfidence: Believing too strongly in one's own knowledge
- Escalation Phenomena: Unwillingness to abandon courses of action that have been decided upon previously
- Association Bias: Reusing strategies that were successful in the past, regardless of whether they fit the current situation
- Groupthink: Overemphasizing group consensus and cohesiveness instead of bringing out unpopular ideas

Simon developed the idea that managers "satisfice" by choosing a satisfactory course of action that is "good enough". His research found human decision makers have limited information processing capabilities and resort to satisficing when faced with time constraints, minimal information, and a limited ability to process all relevant information. (Simon, 1977)

The purpose of a DSS is to convert decision making from an art into a scientific, more rational approach. Relying on a DSS can help managers avoid some of the common mistakes listed above. A DSS can be also be an invaluable tool to justify NAVAIR programs and decisions made by PMAs and APMLs. A DSS can help a manager frame a problem, collect more pertinent information, develop and evaluate feasible courses of action, test assumptions, and select the best solution to achieve the desired objectives. The original vision of the LMDSS application was to provide such support to PMAs and APMLs in order to achieve life cycle cost savings and improve readiness in an environment of shrinking budget authority.

The literature concerning DSS architecture contains various structural views of a DSS concept with each author using unique nomenclature to describe the parts. Most descriptions break down a DSS into three conceptual components: (1) a user/system interface, (2) data management, (5) and model management (Ariav and Ginzberg, 1985).

One view of a DSS describes it using a Dialog Data Model (DDM) paradigm. This paradigm states all DSSs contain, in one form or another, three major components: a Dialog between the user and the system, the Data supporting the DSS, and Models that provide the analysis (Sprague, 1996). Our search of the DSS literature was unable to uncover any author who did not list a model base or model capability as a key component of a DSS.

4. Modeling within Decision Support Systems

a) Capabilities of a DSS Model

Models provide powerful analytical capabilities to a DSS. The capability of a DSS to simulate a process with a model and conduct what-if analysis is what separates it from a traditional CBIS. Sprague (1980), Ariav and Ginzberg (1985) determined the key capabilities of the model component within a DSS to include:

- The ability to easily create new models and update parameters
- Support of a model directory containing all available models
- The capability to interface with databases to retrieve data, store model output, and input data to other models through databases
- Access to a library of model "building blocks"
- Support of a Model Base Management System (MBMS) containing mechanisms to store, catalog, link and access models

b) Four Types of Modeling Activities

The four types of analytical modeling that can be found in a DSS are: (1) what-if analysis (2) sensitivity analysis (3) goal seeking analysis and (4) optimization analysis (O'Brian, 1993).

What-if analysis involves making changes to process variables or variable relationships and observing the resulting changes in the output variables. Sensitivity analysis is a special case where only one variable is changed repeatedly to see the affect

on other system variables. Goal seeking analysis sets a target value or goal and changes various variables until the goal is achieved. Optimization analysis is finding the optimum value for selected variables, given certain constraints. (O'Brian, 1993)

c) Why Models are Hard to Implement

The difficulties inherent in building models today are the very same ones Little (1970) wrote of in his often cited research. His conclusions may help to explain why LMDSS does not currently contain models. He noted four reasons why managers do not use models more widely:

- Good models are hard to find. Models, which accurately depict management control and environmental variables, are difficult to build.
- Good parameterization is even harder. Metrics and accurate, timely data are a mandatory requirement. Complex, high quality design work is required and expensive.
- Managers don't understand the models. A manager is responsible for his decisions and will not trust the output from a model he does not fully comprehend. Often, a manager will choose a simpler analysis that he can grasp over a model whose assumptions are partially hidden and contain complex statistical manipulations.
- Most models are incomplete. An incomplete model can pose a serious risk to optimization analysis.

C. SOFTWARE DEVELOPMENT LITERATURE

Since 1991, the LMDSS development effort has faced more than its share of obstacles. LMDSS meets the Standish Group's criteria for a challenged software project because it is over budget, has exceeded its original time estimate, and contains fewer features than originally specified (Standish Group, 1999). Research is now available which can help managers, developers, and clients better understand the risks and classic mistakes of the software development process. Research literature was selected to show how prevalent the LMDSS situation is among other organizations and to provide needed guidance to software developers seeking to bring such projects under control. Proven

fundamental strategies are presented which can significantly assist software development teams in their efforts to rapidly achieve their objectives within realistic cost constraints.

1. The Software Crisis

The Standish Group's (1999) research has shown only nine percent of software development projects within larger companies are completed on time and on budget. The average cost overrun for these projects was 178 percent. In 1995, American companies spent an additional $59 billion to complete software projects that exceeded their original time estimates. The average project overrun is 222 percent of the original time estimate. Excessive schedule pressure occurs in 75 percent of all large software projects and close to 100 percent of all very large projects (Jones, 1994). The average software developer in the United States works 48 to 50 hours a week (Krantz, 1995).

> In this environment, it isn't surprising that general job satisfaction of software developers has dropped significantly in the last 15 years (Zawacki 1993), and at a time when the industry desperately needs to be recruiting additional programmers to ease the schedule pressure, developers are spreading the word to their younger sisters, brothers, and children that our field is no fun anymore (McConnell, 1996, pg. xviii).

Survey results show there are plenty of organizations struggling to get software development projects under control. Most are trying to overcome the same people, process, and technology issues faced by NAVAIR's LMDSS development team. The first step to improving the software development process is to identify the ineffective practices and classic mistakes. The second step involves a return to effective, proven fundamental software development practices. The third step is to manage identified risks to avoid major setbacks. (McConnell, 1996)

2. Classic Mistakes Leading to the Ten Most Serious Risks to Software Development

McConnell (1996) identified 36 classic mistakes in the software development process, which can lead to a failed program. These classic mistakes are described in Appendix A. Based on research results involving Software Productivity Research (SPR)

assessments, Capers Jones (1994) reported the mistakes that contribute the most to the failure of software projects as:

- Lack of historical software-measurement data
- Rejection of accurate measurement estimates
- Failure to use automated estimating and planning tools
- Excessive, irrational schedule pressure
- Creeping (new and unanticipated) user requirements
- Failure to monitor progress and to perform formal risk management
- Failure to use design reviews and code inspections

From a total sample size of 365 respondents representing 8,380 software applications, The Standish Group (1999, p. 5) conducted four focus groups and interviews with various IT managers. Based on the previously discussed definition of a challenged software project, they identified ten factors, that contribute to such a project:

- Lack of user input
- Incomplete requirements and specifications
- Changing requirements and specifications
- Lack of executive support
- Technology incompetence
- Lack of resources
- Unrealistic expectations
- Unclear objectives
- Unrealistic time frames
- New technology

Once the mistakes and ineffective practices have been identified, they must be corrected and replaced with proven management, technical and quality assurance (QA) fundamental practices. After completing a study of ten "best projects," one researcher concluded,

> If there was one high-level finding that stood out, it is that best projects get to be best based on fundamentals. All of us know the fundamentals for good software--the difference is that most projects don't do them nearly so well and then get into trouble. (Hetzel, 1993, p. 151)

3. Management Fundamentals

Management fundamentals involve estimating the size and characteristics of the project (including software functionality and complexity), assigning adequate resources, creating a plan, and monitoring and directing the plan to stay on course. Effective estimation strategies are essential to developing a realistic plan upon which both managers and developers can depend. (McConnell, 1996) The best projects are characterized by strong up-front planning to define tasks and schedules (Hetzel, 1993). A software development project should include:

- Estimation and scheduling
- Determining how many people to have on the project team, what technical skills are needed, when to add people, who the people will be
- Deciding how to organize the team
- Choosing which lifecycle model to use
- Managing risks
- Making strategic decisions such as how to control the product's feature set and whether to buy or build pieces of the product (McConnell, 1996, p.56)

Once the plan is developed, it has to be monitored to ensure all cost, schedule, and quality milestones are met. Fundamental management tracking activities include: task lists, status meetings, status reports, milestone reviews, budget reports, and

management by walking around. Fundamental technical tracking events include technical audits, technical reviews, peer reviews, and quality gates to ensure functional objectives are met at the appropriate milestone. (McConnell, 1996) Not implementing tracking procedures properly can have disastrous effects. Jones (1995, p. 87) reported that, "Software progress monitoring is so poor that several well-known software disasters were not anticipated until the very day of expected deployment."

> If you don't track a project, you can't manage it. You have no way of knowing whether your plans are being carried out and no way of knowing what you should do next. You have no way of monitoring risks to your project. Effective tracking enables you to detect schedule problems early, while there's still time to do something about them. (McConnell, 1996, p. 57-58)

Collecting metrics is a critical management requirement to track and analyze software quality and productivity. Most projects collect measurements of cost and schedule targets, but such data doesn't provide the insight needed to reduce program costs or shorten time schedules. A knowledge of specific metrics needed to analyze project status, quality, and productivity is required to know whether or not a project's development speed is improving or degrading. (McConnell, 1996)

The importance of metrics in planning and estimating is reinforced by Jones (1996, p. 104):

> Software failures are caused primarily by errors and poor judgement on the part of managers, executives, and clients - not errors made by the technical teams. The root cause of these failures is the lack of accurate measurement data, which blinds management and clients to what is possible and what might be possible.

4. Technical Fundamentals

Requirements management involves gathering and documenting user requirements, tracking the project design and code, and managing all changes for the entire project (McConnell, 1996). A Standish Group (1994) survey of over 8000

software projects found lack of user input, incomplete requirements, and changing requirements were the top three reasons for late, over budget projects with less than anticipated functionality. The fundamentals of requirements management are:

- Requirements analysis methodologies including structured analysis, data structured analysis, and object oriented analysis
- System modeling practices such as class diagrams, dataflow diagrams, entity-relationship diagrams, data dictionary notation, and state transition diagrams
- Communication practices such as Joint Application Development, user-interface prototyping, and general interview practices
- The relationships between requirements management and the different lifecycle models including evolutionary prototyping. (McConnell, 1996, p. 62)

Research has shown that the cost of reworking software is smaller by a factor of 50 to 200 in the earlier phases of the development cycle than waiting until the construction or maintenance phases to correct them. This puts a high emphasis on early error detection and getting requirements correct the first time. (Boehm and Papaccio, 1988)

Software configuration management is defined as the "methodical storage and recording of all software components and deliverables as projects are under development" (Jones, 1994, p. 556). It includes evaluating proposed software changes, monitoring changes, updating planning documents, keeping records of all previous versions, and tracing backwards to original requirements. Automated tools are available which can help developers synchronize, cross-reference, integrate, and update specifications, graphics, user information, source code, defect repairs, and test cases. Configuration management is a requirement for military software and often represents a significant cost factor. (Jones, 1994)

Poor configuration management can allow developers to write code that is incompatible with code written by other team members resulting in expensive rework. Jones (1994) reported that 30 percent of U.S. software producers had no configuration control automation of any kind. About 30 percent had some form of source code automation, but no automation for documentation, test cases, and defect tracking. For a nominal 10,000 function point project, Jones reported an added cost of 168 man-months for projects that failed to use automation. For large projects, he reported configuration control to be a critical path item.

5. Quality Assurance Fundamentals

a) The Cost of Software Defects

Research has overwhelming shown that identifying and correcting software defects early in the development process can generate significant savings in both time and money. Every hour spent on defect prevention will reduce a project's rework time by three to ten hours. After surveying approximately 4000 projects, Jones reported one of the most common causes of schedule overrun was poor quality software. (Jones, 1994) Another survey conducted at 59 government and industry software sites examined 296 software projects and found that quality assurance was a significant problem at 63 percent of the sites assessed (Kitson and Masters, 1993).

Late projects are particularly vulnerable to shortening the QA process in response to pressures to meet deadlines. Surveys have found that software products developed under excessive schedule pressure have reported up to 4 times the number of normal defects (Jones, 1994).

b) Strategies in Achieving Quality Software

The most common strategy for finding software defects is testing. Testing should include unit testing, where the developer checks his own code, and system testing, where an independent tester checks the application to verify it works as advertised. The

best way to implement testing is to conduct it in a manner where errors can be identified and corrected as early as possible. (McConnell, 1996)

A key element of the QA process is formal technical reviews. Technical reviews include formal design reviews, walkthroughs, internal code reading, and inspections.

Formal design reviews provide feedback to management concerning the status of the software project under development. They typically occur at the end of the various development phases and based on their results, management decides whether or not the product is ready to proceed to the next phase.

Walkthroughs are meetings where two or more developers form a peer review team to inspect specific sections of a co-workers code with the purpose of improving quality. Walkthroughs are essential to the QA process because they can be used to detect software defects well before normal testing is accomplished. (McConnell, 1996) Documenting these reviews is accomplished through a walkthrough summary report that contains what was reviewed, who reviewed it, and what findings and conclusions were reached.

Code reviews are more formal than walkthroughs and usually limited to inspections of only code. A code review consists of a developer passing his work to two or more reviewers. The reviewers read the code and report any discovered defects to the author of the code. (McConnell, 1996) A study at NASA's Software Engineering Laboratory by Card (1987) found that internal code reading procedures detected twice as many defects per hour of effort as testing.

Software inspections are technical reviews where each design component is inspected at the requirements, preliminary design, detailed design, and code phases. Inspections use trained peer teams of three to eight people with each person playing a specific role. A team leader hands out the work to be inspected before the formal meetings. Reviewers examine the work using checklists and arrive at the team meetings with their results. At team meetings defects are identified and a plan of action for

correcting them is developed. Throughout the inspection process data on all defects, hours spent correcting them, and hours devoted to inspections are collected to assist in the improvement of the software development process. (McConnell, 1996) A study by Russell (1991) found that for large programs, each hour spent on inspections avoided an average of thirty-three hours of maintenance. He also noted that inspections were up to twenty times more efficient than testing.

6. Risk Management

Many of the proven, fundamental software development practices described are intertwined and rely on each other to be successfully implemented. Jones (1996, p. 103) states,

> A well-formed risk analysis and milestone-tracking program for software projects depends, quite simply, on successful completion of formal design and code inspections.

The purpose of a formal risk management program is to identify, address, and minimize sources of risk before they create significant obstacles to a software project. The elements of risk management include risk assessment and risk control (McConnell, 1996).

a) Risk Assessment

Risk assessment is made up of risk identification, risk analysis, and risk prioritization. Risk identification simply identifies the factors that represent a risk to a software project's successful completion. The most common Management Information System (MIS) software risks identified in the literature are found below:

- Creeping user requirements
- Excessive schedule pressure
- Low quality
- Cost overruns

- Inadequate configuration control (Jones, 1994, p. 29)

Risk analysis involves determining the impact of each risk identified. Risk analysis can involve estimating probabilities, the size of losses, and the levels of exposure in time periods such as weeks or months. Risk analysis may also involve the use of performance and cost models, decision analysis, and quality factor analysis.

Risk prioritization follows the identification and analysis phases with the development of a priority list of risks so risk reduction efforts can be focused on the greatest threats. Boehm and Papaccio (1988, p. 1466) noted,

> 80 percent of the rework costs typically result from 20 percent of the problems...The major implication of this distribution is that software verification and validation activities should focus on identifying and eliminating the specific high-risk problems to be encountered by a software project, rather than spreading their available early-problem-elimination effort uniformly across trivial and severe problems.

b) Risk Control

Once risks have been identified, measured, and prioritized, they have to be controlled and minimized. Risk control activities include risk management planning, risk resolution, and risk monitoring.

The purpose of risk management planning is to develop a written plan to address the highest priority risks identified earlier. The plan can be as simple as a paragraph for each risk detailing the who, what, where, how, and why of each risk's management strategy. The plan should describe how risk management strategies will be monitored, how eliminated risks will be closed out, and what new risks have been identified. (McConnell, 1996)

Risk resolution is the implementation of the risk management plan to avoid, reduce, transfer, eliminate or control identified high priority risks. Prototypes, simulations, and benchmarking may be used in this phase to investigate and resolve risks.

Risk monitoring also involves implementing the risk management plan by tracking risk management actions and documenting identified emerging risks. Risk monitoring procedures often include milestone tracking, risk reassessments, and documenting corrective action.

7. Research Recommendations for Avoiding Disaster

Based on his years of researching hundreds of software projects, Jones (1996, p. 104) supplements the proven practices previously described with some additional recommendations to achieving success in software development efforts:

- Look at the actual results of similar projects
- Make planning and estimating formal activities
- Plan for and control creeping requirements
- Use formal inspections as milestones for tracking project progress; and
- Collect accurate measurement data, during the current project, to use with future projects

III. BACKGROUND INFORMATION

A. DEVELOPMENT HISTORY

1. Background Information

The end of the Cold War created a new world order with the United States as the only surviving superpower. After the fall of the Berlin Wall, the American public and members of Congress anticipated massive cuts in the military. An immediate sense of increased security prevailed, resulting in demands for heavy reductions in defense spending. The term "peace dividend" was coined and popularized as it was felt that the savings generated would be applied to domestic programs and to help lower the deficit. Over the next several years, the defense budget was drastically reduced, to the point where the fiscal year 1999 defense budget represented a 39 percent drop from spending levels in the 1980s. The defense budget is now equal to just 3.2 percent of our gross national product, a level not seen since the 1930s.

The magnitude of these reductions was felt throughout the Department of Defense. Military bases were closed, ships were decommissioned, entire air wings were disestablished and thousands of fully trained troops were discharged. Acquisition programs that had been funded for years were severely restricted or canceled out-right. The only thing in the military that wasn't cut back was the operational tempo. Fewer troops were expected to fulfill the same requirements with older and less reliable equipment. Operating and support costs skyrocketed as aging aircraft, tanks and ships were pushed beyond their expected useful life in order to meet operational needs.

Program managers, trying to do more with less, were forced to look closely at their programs and examine all expenditures in an effort to eliminate unnecessary cost drivers. For most program managers, this was a tedious and time-consuming task; for some it was simply impossible. The sheer volume of data, which were distributed in

technically diverse and geographically separated databases, made the job prohibitively expensive.

Analysts at NAVAIR 4.0 and NAVICP, formerly the ASO, were charged with the task of assessing the logistics health of aviation programs, focusing primarily on readiness, supportability, and cost. This involved the time-consuming manual efforts of pouring though the available data in an effort to minimize costs. After several months of effort, they concluded that the information systems available to them were inadequate for the job. If they were to meet the demands of cost reductions through analysis of the disparate, poorly maintained databases, program managers sorely needed a tool that could provide a central data repository and support the analysis of the data.

With this in mind, steps were taken within NAVAIR to assess the feasibility of designing and implementing a DSS specifically to support logistics decisions. In this manner the concept of LMDSS was founded.

2. LMDSS Fundamental Structure

As stated above, the driving requirement behind the push for the development of a DSS for logistics management was the need for a tool to facilitate measurements to use in the planning and identification of targets for cost reduction. The original vision statement for LMDSS required the detailed assessment and development of a DSS which would be the primary tool for APML/Weapon System Managers (WSM) to achieve a "continuous, measurable reduction in life-cycle costs while maintaining operational readiness and sustainability." (Naval Air Systems Command, 1993).

The specific goals of the initial LMDSS program as designed within the Naval Aviation Logistics Data Analysis (NALDA) system were as follows:

- To be the primary DSS to achieve cost-effective logistics management
- Improve more timely (daily) receipt of AV3M and configuration data
- Create cost-effective consolidation of central, upline AV-3M data systems

- Provide the ability to access centralized Fleet-wide, near real time operational and readiness data from NALDA in accordance with DoD data security regulations. (Naval Air Systems Command, Program Manager's Charter, 1997)

In order to meet these objectives, it was essential to integrate vast quantities of diverse data contained in multiple legacy stovepipe databases into one central repository. The LMDSS requirement document (LMDSS Requirements Document/Statement of Work, 1993) also identified other key features as being essential to a successful program. These included:

- Timely, precise responses to queries independent of type data or type/model/series (TMS)
- A user friendly system that did not require extensive computer knowledge or training
- Ease of access to the system as well as maximizing the eligible number of personnel who could access the system
- Detailed statistical packages embedded in the program to provide projections of outcome based upon changes to maintenance and supply parameters
- Both a structured modular approach to data recovery and an ad hoc Structured Query Language (SQL) capability
- Assist tools to facilitate easy development of queries
- Integration of the depot level AV3M data and the Naval Depot Logistics Management System (NDLMS) into the NALDA phase II existing database structure
- Graphical User Interface (GUI) capabilities designed to produce presentation quality graphics on data obtained from queries
- Inclusion of an Evaluation and Selection of Alternatives Module (ESM) based upon return on investment principles

- Inclusion of implementation and status tracking modules to document the actual implementation of actions recommended in the ESM module and to establish an audit trail

According to the initial Statement of Work (SOW), rapid prototyping was the software development method used to develop the initial prototype. The SOW also required the LMDSS software development teams to maintain maximum flexibility and "react with rapid turn around to additional requirements and changes to requirements levied by the LMDSS functional design team" (LMDSS Requirements Document/SOW, 1993).

At this time, the process for Major Acquisition of Information Systems (MAIS) was still a relatively new concept. Exacting measures and legislation were not in place to help identify means of formally structuring software development processes. Most legislation was developed in response to unforeseen difficulties arising from haphazard and unstructured software development processes.

B. LMDSS' ROLE IN SUPPORTING NAVAL AVIATION FOR THE 21ST CENTURY

1. LMDSS Within the NALDA System

LMDSS is currently a sub-component of the NALDA Phase II project. NALDA has been operational since the early 1980s, although LMDSS was not formally initialized until the early 1990s. NALDA is the Navy and Marine Corps central aviation maintenance and logistics Automated Information System (AIS). Its mission is to provide Integrated Logistics Support (ILS), engineering functions and achieve readiness and affordability process improvements through the implementation of advanced data collection, compilation and management techniques (Naval Air Systems Command, Mission Need Statement, 1997). Other applications that fall under the umbrella of the NALDA system include logistics planning, management, administrative, budgeting and

resource allocation for aviation weapon systems and related support equipment. For a more detailed description of NALDA II, refer to Appendix B.

NALDA Phase I currently operates on an AMDAHL 5995 mainframe located at the Defense MegaCenter in Mechanicsburg, Pennsylvania, but it is in the process of being phased out. This system is redundant, consists of outdated stovepipe systems with restricted functionality, and does not meet the requirements as set forth in current doctrine. In addition, many of the older legacy systems are not Year 2000 (Y2K) compliant and the Defense Information Systems Agency (DISA) has mandated all such systems be made Y2K compliant or be shut down by 15 March 1999. The NALDA system is scheduled to be completely converted to an IBM RS/6000 environment using the Advanced Interactive eXecutive (AIX) operating system and employing an Oracle 7.3 relational database management system by the end of second quarter FY99. The current mainframe system, a Reduced Instruction Set Computing (RISC) SP machine, is operational but multiple unforeseen difficulties with the data loads has caused delays in the schedule. Parallel operations were planned to be in effect for a three month period from January to March 1999 in order to minimize the risk of decreased performance while identifying glitches in the new system. During this time period, NALDA I is scheduled to run on the server at Mechanicsburg while NALDA II runs concurrently on the server at NAS Patuxent River. As of May 1999, the dual system approach was extended to continue through the end of the fiscal year.

2. LMDSS Within the Department of Navy (DON) Chief Information Officer (CIO)/Global Combat Support Structure (GCSS)

The Office of Secretary of Defense Certification (December 21, 1995) for the NALDA system defined the NALDA migration strategy. The NALDA II program, when completed, will ensure compliance with the Department of the Navy Information Technology Strategic Plan which requires logistic support applications provide a seamless blend of operational and administrative information to all users (Naval Air Systems Command, Program Manager's Charter, 1997). In addition, the plan was

structured in accordance with the Technical Architecture Framework for Information Management because it established a long-range goal of open systems architecture. It also met Defense Information Infrastructure (DII) Navy Common Operating Environment (COE) criteria. NALDA Phase II plans meet the Level 5 DII COE standard as defined in the Integration and Runtime Specification which enables it to be interoperable with other Level 5 or higher DII COE systems like the Joint Maritime Command Information System (JMCIS) or the Global Combat Support System (GCCS). (Naval Air Systems Command, Operational Requirements Document, 1997)

C. CURRENT LMDSS ENVIRONMENT

1. Initial Prototype Development

The LMDSS Statement of Work was developed in 1993. The initial prototype was completed in 1994. It used the current NALDA IBM RISC System/6000 Model 970 at ASO Philadelphia and other regional machines located at NADEP and Naval Air War Center (NAWC). The relatively new X-windows specifications, as developed by the Massachusetts Institute of Technology, were incorporated as the standard for GUIs. X-client and X-server structures were used. All programming on the initial prototype was done in Ada programming language. AIX operating systems which are IBM's version of the single user version of MULT "ICS" (UNIX), were used exclusively and Transmission Control Protocol/Internet protocol (TCP/IP) was the only protocol used in NAVAIR's wide area network (WAN) connectivity plans. In addition, the Oracle relational database concept was the basis for the organizational matrices of the LMDSS database.

The prototype worked well, but several of the initial requirements were not met. The UNIX operating system was unfriendly to all but the most highly trained computer personnel. The X-client and X-server implementation mandated the usage of a direct local area network for personal computer accessibility. For those personnel on a WAN, the X-windows required a 56KBit/sec connectivity rate. Although that rate is fairly common in 1999, five years ago it was difficult and expensive to obtain reliable T-1 line

capability. Only the PMAs and APMLs located at NAS Patuxent River could get access to LMDSS. The contractors and analysts hired by PMAs for the majority of their data analysis did not have access to LMDSS because they were not part of NAS Patuxent River WAN. At this point, LMDSS was still considered a logistics management tool for high level logisticians, and according to later surveys, most of them were simply not using it (Moore and Snyder, 1998).

2. Transition to Web Based Format

In 1995, NAVAIR determined the detriments of the existing prototype did not meet the requirements as set out in the SOW. The decision was made to abandon the UNIX/X-windows environment in order to develop a web-based system with Common Graphics Interface (CGI) scripting. The Ada programming language was abandoned for HyperText Markup Language (HTML) and Practical Extraction and Report Language (PERL) because it was not suited for a major database management system. Although these decisions directly impacted major software development issues, the user group was neither expanded nor queried for inputs. A thorough risk analysis to determine the impact of these decisions was also not conducted and documented. The project fell behind the scheduled baseline and costs exceeded earlier estimates. As shown in the review of the software development literature, this is a common occurrence within the software industry. The Standish Group (1999) reported only nine percent of software developed by larger companies come in on-time and on-budget. Jones (1994) reported that most software development projects are cancelled because they fail to properly conduct requirements analysis, identify user needs, and conduct risk analysis/reduction assessments. As a result, instead of anticipating problems, the LMDSS team fell into the practice of reacting to events as difficulties arose.

3. Integration into NALDA Program

It was shortly thereafter that the decision was made to make LMDSS the basic interface to all NALDA data. The original LMDSS contract had been awarded to a small software development firm. It quickly became apparent the firm did not have the

expertise in HTML, CGI Scripting, ActiveX and data warehousing to meet the needs of the revised program specifications. When their contract was up, a major programming contractor was selected to replace the small business. Several of the firm's former employees stayed on as Federal Government Service workers. During this transition the LMDSS programmer pool was reduced from over thirteen full time programmers, to only three who were concurrently seeking other employment. It is presumed that a large chunk of corporate knowledge was lost in this contractor change, as not all programmers were hired on by the new company.

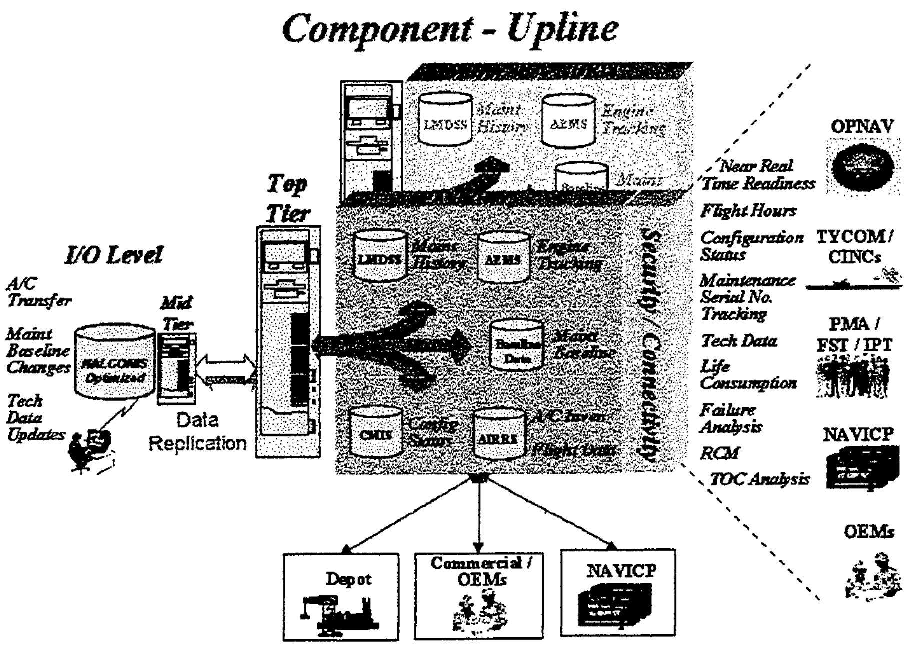


Figure 1 NALDA Upline Application

LMDSS was changed once again from the basic interface for all of NALDA, to its current status as just the component of the NALDA II system that provides access to the reliability and maintenance portion of the NALDA II database structure. Figure 1 displays the current NALDA upline configuration and includes the new functional relationship of LMDSS within the NALDA II system (NAVAIR 3.6, 1999). LMDSS does not do configuration management (CM), although it helps track CM data. When it

first was produced in 1994, it was hoped by NAVAIR that LMDSS would be the end-all, solve-all for any questions concerning reliability, readiness, cost, and configuration management for the Navy's aircraft. This is no longer the case; however, when the development of LMDSS is complete, it will have all the detailed data from approximately 2.5 million maintenance action records/month. Currently, NAVAIR has archived 32 months of maintenance data online and 11 years of flight data (Interview with Mr. Joe Joseph, 1998).

Unfortunately, under the new NALDA II Acquisition Program Baseline (APB), LMDSS developers were forced to meet the deadlines established for the Milestone III Decision Authority. The first increment, which consisted of the consolidation of the configuration management and AV-3M systems, was to be completed by February 1998. In the process of transitioning from one software language and platform to another and to meet the goals of the NALDA program, many DSS items were discarded. Graphics capabilities and some of the statistical forecasting and modeling modules were scrapped.

What makes the current application of LMDSS useful is it's summary tables that can provide, for example, the top five items in the last five years with the worst reliability performances for the maritime patrol aircraft (P-3) community. Another strength is its ability to drill down from the summary data to specific part numbers and locations. Even with its reduced capabilities caused by the multiple changes in software format and program structure, the remaining capabilities will enable NAVAIR program managers to identify areas to save money so they can use the funds to purchase more important items that are not funded. In short, doing more with less.

4. Current Program Funding

Funding reductions have had the most detrimental impact on the LMDSS program. LMDSS received its initial charter prior to the finalization of the plans for NALDA Phase II, although funding for LMDSS was and still is received mainly under the NALDA system. According a phone conversation with the Operations/Planning Department Head for NAVAIR 3.6.2, the LMDSS system has always been funded out of

excess year end funds and primarily from the NALDA program. For the last few years, LMDSS has been funded "out of hide" from NAVAIR 3.6.2 Operations and Maintenance (O&M) funds, according to the 1999 LMDSS Quality Assurance Leader. This constant scramble to obtain funding caused numerous hardships during the entire developmental process.

In general, the NALDA AIS codes fall under Tab G of the Program Objective Memorandum (POM) 98/99 under AIS code 1274 (Naval Air Systems Command, Acquisition Program Baseline, 1997). The costs identified with the parent NALDA program included development, implementation and operating support costs. All funds for the development of software end with the start of FY00. Implementation funding for software is minimal until FY00, when it triples, but it should be noted that the total amount budgeted once the implementation starts is significantly less than in previous years as displayed in Table 1 below. The APB also stated that the year-end funds are often used to enhance the upgrade and modernization schedules.

	FY 1999	FY 1999	FY 2000	FY 2001
SW Development	3,758,000	1,844,000	0	0
SW Implementation	250,000	459,000	681,000	693,000

Table 1 NALDA Costs excerpted from NALDA Phase II Acquisition Program Baseline, 1997.

At this time, the NALDA program has missed milestones and is not receiving any additional funding. LMDSS is still not functioning as it should and all additional developmental funding is being redirected to getting the LMDSS application running smoothly. This is hampering the developmental efforts of other systems (Phone interview Jahn/Evanoff, 1999).

5. Current LMDSS Scheduling Plans

Under the new APB, LMDSS developers now had to meet the deadlines established for the Milestone III Decision Authority. The first increment, which consisted of the consolidation of the configuration management and aviation 3M systems, was to be completed by February 1998. Figure 2 displays how the completion of LMDSS is an integral part of the NALDA system (NAVAIR 3.6, 1999). In the process of transitioning from one software language and platform to another and to meet the goals of the NALDA program, many DSS items were discarded. Graphics capabilities and some of the statistical forecasting and modeling modules were scrapped.

One of the major setbacks is the lack of preformatted reports for the system. Nearly 50 reports were initially developed and coded but since the structure of LMDSS changed it has forced the continued running of the Mechanicsburg site in order to ensure continuous exchange of data with the Fleet. The question NAVAIR is now trying to answer is should it either pay to update the original coding, or take a different attack and develop a structured query language based means of obtaining the report forms.

Throughout this transition, the LMDSS program was plagued with other setbacks which resulted in more time delays:

- A Product Support Team member who pushed hard to transition to the HTML format was transferred taking with him a lot of corporate knowledge.
- The merging of databases resulted in some corrupted data.
- A hacker successfully attacked the LMDSS server corrupting invaluable data and resulting in LMDSS being taken off line to develop additional security measures such as firewall integration.
- Further testing revealed LMDSS's Active X programs could not be downloaded to users with certain web browsers who were not accessing the Internet with at least a T-1 connection.
- The resulting decision to abandon ActiveX for Java caused additional delays due to training deficiencies and data reliability problems.

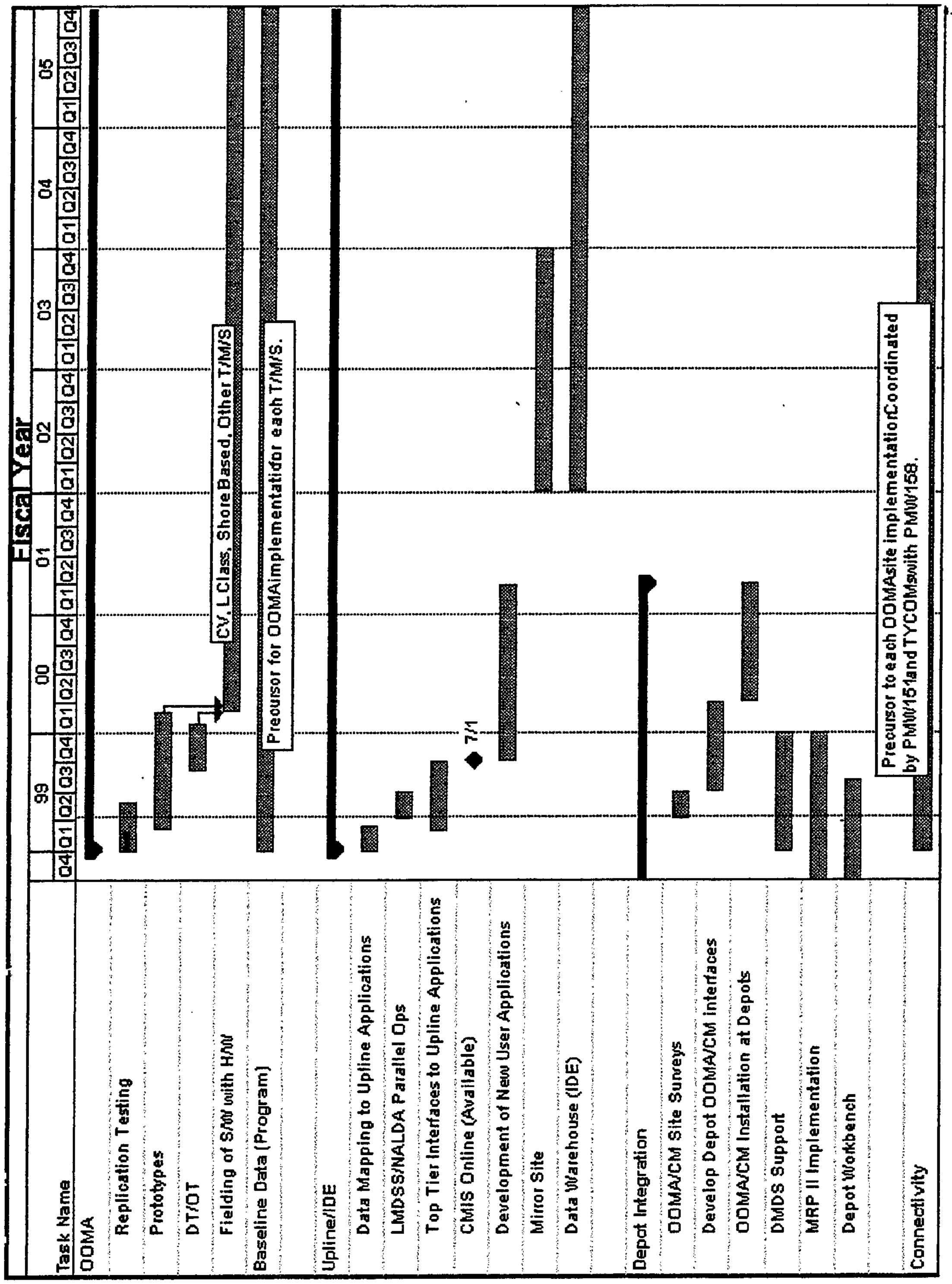


Figure 2 AMSR FY 2005 Implementation Plan

In 1997, proposed performance measures were written for NALDA Phase II. Areas mentioned in this document related to the LMDSS system were:

- User satisfaction
- Logistic support costs
- Data accuracy and timeliness

Unfortunately, this document did not accurately outline specific performance measurements that could be used in the developmental or implementation phases of the LMDSS project. For example, the User Satisfaction section proposed that the effectiveness of the act of combining the NALDA II subsystems be measured through the use of a survey conducted six months after the technical architecture was implemented. Although a functional requirements document was developed, it was not available for review. It is possible that more specific measures were developed in this document. (Naval Air Systems Command, Performance Measures, Proposed, 1997)

IV. METHODOLOGY

A. RESEARCH QUESTIONS

The primary research question is: "Does LMDSS meet user requirements?" The subsidiary research questions mentioned earlier are:

- How can LMDSS be improved to better meet managerial needs?
- What are the significant decisions users would like LMDSS to support?
- How has LMDSS been funded?
- How can NAVAIR improve the LMDSS program?
- What can future software developers learn from studying the LMDSS project?
- What are the key attitudes and opinions of LMDSS users?

The investigation into the last of these questions led to the additional difference (group comparison) questions below:

- Do military and civilian data analysts at the various organizational levels (fleet command, type command, system command, etc.) have significantly different LMDSS user requirements?
- Do various categories of users (officers, enlisted, General Schedule--GS, civilian) have different LMDSS requirements?
- Is there a difference between the attitudes of LMDSS users at various organizational levels concerning modeling/simulation, graphics, exporting data, and the ad-hoc query (IQ) tool?
- Is there a difference in the frequency of LMDSS use among the LMDSS organizational groupings?

B. DESIGN OF THE STUDY

This research is best described as an ex-post facto design consisting of a one-shot questionnaire survey (Campbell & Stanley, 1963) triangulated with face-to-face and phone interviews. The term ex-post facto is an appropriate description because the research team did not control or manipulate the independent and dependent variables identified. The research conducted on the LMDSS project was exploratory or pre-experimental in nature. Simple random samples were chosen from a population of 843 LMDSS users registered with NAVAIR 3.6.2. A Web-based survey, face-to-face interviews, and phone interviews were the methods used to collect data. Past NAVAIR LMDSS briefs and documents posted on the NAVAIR 3.6.2 Web site were secondary sources of data (NAVAIR, May 1999).

C. CONDUCT OF THE STUDY

1. Research Strategy

a) Prestudy

The prestudy phase of this research began in November, 1998 during a three-day visit to NAVAIR 3.6.2 at the NAS Patuxent River, Maryland. Fifteen personal interviews were conducted with an emphasis on questioning those individuals directly involved in the management of the LMDSS project. Most of the interviews were recorded and notes were used to document the minor discussions that took place. An exploratory focus group was held on the final day of the visit with the three individuals assigned to the LMDSS Help Desk. The purpose of the focus group was to gain additional insight missed during the interviews and help develop meaningful questions for the forthcoming survey. The focus group was moderated by the thesis authors and videotaped. See Appendix C for a complete list of the questions that were asked. An Access 97 database containing the total population of 843 LMDSS users was received from NAVAIR during this visit.

Upon leaving NAVAIR, the research team traveled to NAS Norfolk and NAS Oceana completing five personal interviews with LMDSS users at the Safety Center, Aviation Intermediate Maintenance Depot (AIMD), Wing, and Squadron levels. These interviews were exploratory in nature and were documented in the same manner as those conducted at NAS Patuxent River.

b) The Pilot Study

The pilot study phase consisted of choosing two random samples from the LMDSS user population, developing and pilot testing phone interview and survey questions, validating email addresses for users within the samples, mastering the web survey software, and setting up a web site to host the survey.

Two systematic, random samples (Cooper and Emory, 1995) were selected from the total population of 843 LMDSS users. A random sample of 289 LMDSS users was selected to participate in the Web-based survey. A smaller sample of twenty-five LMDSS users was chosen to participate in the phone interviews.

The phone interview and survey questions were developed from the information collected during the personal interviews and focus group conducted in the prestudy phase. The initial drafts of both the phone interview questions and the survey questions were emailed to the twenty-eight member LMDSS Quality Assurance Team for feedback. The QA team consisted of logistics and aviation maintenance experts within the NAVAIR domain who were selected by the LMDSS program manager to assist in testing LMDSS modules. The final drafts of both the phone interview and survey questions were developed from the email critiques and phone comments received from the QA group.

The most time consuming task in the pilot study phase was validating the email addresses of the 289 and 25 member random samples. The LMDSS database received from NAVAIR had an abundance of entries dating back from two to four years. Of the original 289 LMDSS users selected to participate in the Web survey, only 213 could be contacted by phone to attain their correct email addresses. All of the 213 users

contacted had access to the Web and were able to provide valid email addresses. These 213 users became the *effective* random sample for the Web survey.

The software application chosen to implement the web-based survey was Perseus Survey Solutions for the Web. Once the completed survey questions were entered into Perseus, they were transformed into a HTML format and posted on the Web. Coding within the survey was designed to send survey responses to a central Perseus server where they were encapsulated and sent back as email to the research team.

c) *The Study*

The study phase involved conducting the phone interviews, soliciting Web survey responses from sample members, documenting the phone interviews, collecting the survey responses, and sending out individual thank-you emails.

Phone interviews, each lasting thirty to forty-five minutes, were conducted over a period of four months. Seventeen of the twenty-five member random sample were interviewed by phone as well as various LMDSS managers at NAVAIR 3.6.2. As the research continued, additional questions arose that were not asked on the initial NAVAIR visit. Volunteer graduate students from the Naval Postgraduate School, who participated in related group projects, were tasked to contact members of the NAVAIR 3.6.2 staff for updated LMDSS information. The authors of this thesis developed the questions that were used and the answers received have been incorporated throughout this body of work.

Initial emails requesting survey participation were simultaneously sent, or "shotgunned", to all 213 members of the effective random sample. As users replied, they were dropped from the shotgun list and sent thank-you emails. Email addresses were constantly changing throughout the study phase of the research. Even after all 213 emails had been verified, at least ten to fifteen emails had to be corrected after each of four attempts to solicit additional survey responses from sample members. After the third solicitation attempt, approximately 120 of the 213 LMDSS users contacted replied. A final round of ninety-three individualized emails were sent to the remaining non-

participants requesting assistance in completing the survey. Thirty-two additional responses were received. After four weeks, a total of 152 LMDSS users from the 213-member sample replied to the Web survey. Individual thank-you emails were sent to each replying sample member within one day of receiving a response.

Phone interviews were taped, with the permission of the interviewees, and later transcribed into notes. Only the interview questions developed during the prestudy and tested during the pilot study were used during the phone interviews with individuals from the twenty-five member sample. Additional sets of questions were customized for the each of the NAVAIR LMDSS managers contacted by graduate students throughout the study phase. Phone interviews proved difficult to complete because interview appointments were often cancelled at the last minute due to interviewee work conflicts. After months of interviewing it became more efficient to conduct the interview during the initial contact phone call instead of making future appointments.

D. THE SAMPLE

1. Random Selection Procedure

The purpose of random sampling in this study was to attain samples of users that represented the characteristics of the larger population of LMDSS users. It can be argued that studying these samples enables accurate conclusions to be reached about the larger LMDSS user population. In order to strengthen this argument, a systematic random selection process was implemented to capture at least fifteen percent of the population to participate in the Web survey. Planning for a maximum non-participation rate of fifty percent, the initial size of the survey sample was approximately twenty five percent of the population. The systematic random selection process began when a seed number between one and eight was literally drawn out of a hat to select the first member of the sample. The seed number drawn for the larger of the two samples was a five. Every fourth user was then selected from the 843 LMDSS user database which was alphabetically ordered by last name. The resulting sample consisted of 289 users. A

similar procedure was chosen to select the smaller, second random sample of twenty-five names. The seed number randomly chosen was seven. The 289 user random sample was chosen to participate in the Web survey while the twenty-five user random sample was chosen to participate in the phone interviews. Additional Access 97 databases were developed to manage both random samples. (Cooper and Emory, 1995)

It was assumed that the size of the twenty-five user sample chosen for the phone interviews was too small to enable precise estimations or inferences about population characteristics. The primary purpose of creating the smaller sample was to attempt to gain some additional insight by using open-ended questions that were more appropriately delivered by a phone interview than a survey. Time and workload limitations also influenced the decision to limit the number of random phone interviews.

2. Validation of Email Addresses

The NAVAIR LMDSS user database contained many old and outdated entries. This called for an aggressive effort to clean the data. Cleaning the user contact information involved validating the phone number, email, identity, and command/organization of over 350 users contained in the two random samples, the QA team, and managers at NAVAIR. During the period of this research, many commands transitioned to Information Technology for the Twenty First Century (IT-21) standards. This transition resulted in significant changes to email addresses throughout the Navy during the study phase of this research. Maintaining current email addresses on the users belonging to the two samples required an almost daily effort and proved much more time consuming than anticipated. Two to three phone calls were often required to contact each sample member. Many email addresses were retrieved only to change a few months later as Navy commands updated their networks to meet IT-21 standards. Table 2 shows the breakout of how the original random sample of 289 names chosen for the web-based survey decreased to 213 names as a result of the phone number/email validation. Three members who were contacted declined to participate because they believed their contact with the program was so minimal that they could not provide any relevant data.

Of the twenty-five LMDSS users selected to participate in the phone interviews, only seventeen were contacted. Researchers were unable to reach six of the sample members due to changes in both phone numbers and email addresses. The remaining two users failed to keep previously arranged appointments on several occasions and did not return subsequent phone messages.

Reasons for Sample Shrinkage	Number of LMDSS users
Original Random Sample	**289**
Declined to Participate	(3)
Transferred	(31)
Retired	(5)
Changed to an unknown Phone # and Email address	(32)
Effective Sample Remaining for Web Survey	**213**
Total Number of LMDSS Users Who Responded	**152**

Table 2 Shrinkage of Original Random Sample (Web-based Survey)

3. Testing the Effective Sample for Randomness

Due to the large attrition rate of the original 289-user sample, randomness could no longer be assumed. Additional testing was completed to ensure that the effective sample of 213 LMDSS users was still random in nature. Using the same systematic, random selection procedure described earlier (the random seed number selected was eight) a random test sample of 105 LMDSS users was created to be compared with the effective sample of 213 users.

The demographic characteristics of both independent samples were measured based on data found within the NAVAIR database. For each sample, users were assigned to mutually exclusive and exhaustive user categories defined as: Officer, Enlisted, General Schedule (GS), Civilian, and Unknown. All members of both samples were then assigned to mutually exclusive and exhaustive organization types consisting of: Fleet

Command, System Command, Type Command, Program Office (PMA/APML), Depot, AIMD, WING, Squadron, Marine, Reserve, Private Company, and Unknown. The demographic data for both samples is depicted in Tables 3 and 4.

The chi-square nonparametric test was chosen to compare the two independent sample groups because the demographic data as shown in the above tables was nominal and categorical. The requirements of independence between the groups, and mutually exclusive/exhaustive categorical data were met.

	Officer	Enlisted	GS	Civilian	Unknown
Effective Sample of 213 users	26	48	84	47	8
Test Sample of 105 users	16	31	32	22	4

Table 3 Sample Demographics With Respect to User Category

Organization Type	Effective Sample of 213 Users	Test Sample of 105 Users
Fleet Command	7	5
System Command	43	14
Type Command	5	4
Program Office (PMA/APML)	12	3
Depot	27	11
AIMD	8	7
Wing	9	6
Squadron	5	6
Marines	15	8
Reserves	6	1
Private Company	46	46
Unknown	30	30

Table 4 Sample Demographics With Respect to Organization Type

The null hypothesis notation is: $H_o : E_I = T_I$, where E is the effective random sample and T is the test sample. The null hypothesis claims there is no difference between the demographic characteristics of the effective 213-user sample and the 105-member test random sample. The level of significance (the probability of rejecting a null hypothesis that is true) is .05. Critical values of the chi-square distribution, based on degrees of freedom, were found in a statistical table from Cooper and Emory (1995, p. 659). The chi-square tests comparing the samples, using SPSS statistical software, resulted in the output displayed in Table 5.

Test (.05 level of significance)	Critical Value of Chi-Square Distribution	Degrees of Freedom	SPSS Calculated Critical Value of Chi-Square
User Category Comparison Between Samples	9.49	4	3.461
Organizational Type Comparison Between Samples	19.68	11	9.706

Table 5 Chi-Square Tests of the Two Independent LMDSS Samples

In both chi-square tests comparing the user categories and organization types of the two samples, the SPSS calculated critical value was less than the critical value of the chi-square distribution. The null hypothesis therefore cannot be rejected. The samples are not significantly different at a significance level of .05. Since the effective sample and test sample were not significantly different, the argument can be made that the effective sample of 213 LMDSS users is indeed random and representative of the greater LMDSS user population.

E. INSTRUMENTATION

1. Need for a Custom LMDSS Survey

Since LMDSS is a custom software application developed by NAVAIR for the Navy's use, there was not a commercial, off-the-shelf (COTS) survey instrument

available considered appropriate for the requirements of this research. The questionnaire developed by Moore and Snyder (1998) was designed for a different audience with a different research focus thus their instrument did not meet the needs of this research effort. COTS software was used to implement the Web survey (Perseus), manage the user samples (Access 97), and statistically analyze our survey results (SPSS v.9.0 and S-Plus v. 4.0).

2. Developing and Pilot Testing the Survey Instrument

In order to collect as many responses as possible from the 213 member effective random sample, it was decided to develop a Web-based survey. It was thought the novelty of a paperless Web survey would attract more responses and limit non-response error. Email was used to conduct multiple, rapid requests for user participation. Individually addressed emails seemed to generate a significantly greater response rate than group or shotgun emails to multiple users.

The initial draft of the survey questions was created from the interviews and a focus group conducted at NAVAIR. The focus group was responsible for many of the questions relating to the quality of LMDSS training, the IQ tool, and how LMDSS is used. Pretesting was accomplished by conducting a pilot test of the Web survey to detect any design weaknesses in the survey instrument. The pilot survey was posted on the Web and the twenty-eight member LMDSS QA team was contacted by email and requested to provide feedback. Thirteen survey responses were received. As a result of these responses, the number of open-ended questions in the survey were reduced, several questions considered confusing were rewritten, and options such as: not applicable, unknown, and don't know were included. The final version of the Web survey is found in Appendix D.

3. Pilot Testing the Phone Interview Questions

The phone interview questions were developed in a similar manner as the survey. Initial draft questions were created using input from interviews and the focus group conducted at NAVAIR. The pilot questions were emailed to the LMDSS QA team for

evaluation. As a result of the QA team's feedback, several questions were added and several were rewritten for better clarity. The majority of phone interview questions were open-ended, to allow a level of probing and depth not considered possible by the Web survey alone. Fifteen of the seventeen phone interviews conducted were done by the same researcher to minimize interviewer bias. The questions developed for the random phone interviews are presented in Appendix E.

F. INDEPENDENT AND DEPENDENT VARIABLES

Many authors restrict the term independent variable (IV) to variables that are manipulated. Some researchers define an independent variable more broadly to include any predictors, presumed causes, or influences under investigation. Such independent variables that define attributes of persons or the environment and are not manipulated in the study are called attribute independent variables. (Morgan and Griego, 1998)

The attribute IV chosen as a possible influence on the dependent variables measured in the Web survey was the organization type as previously defined in the chi-square testing of the sample members. Cooper and Emory (1995) define an extraneous or moderating variable (MV) as a second IV that is considered because it is believed to have an influence on the original independent/dependent variable relationship. User category (officer, enlisted, General Schedule (GS), civilian) was suspected to be a MV. Morgan and Griego (1998) describe a dependent variable (DV) as the presumed outcome that measures the effect of the independent variable. An IV typically affects a DV in a way that can be measured. Surveys and interviews are two ways to measure such an effect.

The DVs that were measured in the Web survey for possible IV effects to answer the difference based research questions were:

- Importance of modeling and simulation
- Importance of a graphics capability
- Importance of a capability to cleanly export LMDSS data
- Importance of a structured, ad-hoc query (IQ) tool

- Frequency of LMDSS use.

G. ANALYSIS STRATEGY

Research conducted with attribute variables is limited in its ability to establish proof of causality with any certainty. The standard of causation requires more complex, experimental research approaches where active, independent variables are manipulated over time. The scope of this research is limited to answering the main research questions, and exploring the aforementioned differences between the LMDSS user groups.

Data from the phone interviews were transcribed from tape recordings made by the interviewers. The interview transcripts were analyzed to identify common user attitudes and perceptions. Trends were uncovered and compared with those found in the Web survey responses.

S-Plus statistical software was used to conduct a frequency analysis on the closed-response (specified alternatives) questions within the Web survey. Content analysis was completed on the responses provided from the open-ended survey questions. One-way Analysis of Variance (ANOVA) testing matching one of two possible IVs (organizational type and user category) with each DV measured in the survey was conducted using SPSS statistical software. The one-way ANOVA was used to assist in answering the difference (group comparison) research questions.

Open-responses, free choice of words, from the Web survey were collected and compared using content analysis with the other types of data to provide answers to specific research questions. Data from phone interviews with managers at NAVAIR 3.6.2 was reviewed, summarized, and compared with other data sources.

V. FINDINGS

A. ORGANIZATION OF FINDINGS

The findings in this chapter are presented in the following sections:

- Frequency and content analysis
- Establishing difference null hypotheses
- ANOVA tests
- Phone interview findings
- Interviews with past and present LMDSS managers

1. Frequency and Content Analysis

The material in the first section, frequency and content analysis, includes a detailed analysis of the data collected from the Web-based survey. To assist in analysis, the survey questions were grouped into the following subheadings according to the topic covered in each question:

- Demographics
- Frequency of use
- Hardware/software concerns
- Usage of application
- Modeling/simulation
- Training
- Graphics
- User perceptions.

The presentation of the Web survey responses mirrors the approximate order of the questions as found in the web based survey questionnaire (See Appendix D).

A variety of statistical software applications were used to conduct the analysis. SPSS version 9.0, S-Plus version 4.0 and Excel 97 were used to generate the charts and graphs contained in this chapter. A combination of summary tables, percentage histograms and figures were used to accurately display the findings for each survey question.

2. Establishing Difference Null Hypotheses

In the second section, establishing difference null hypotheses, the null hypotheses explored in this thesis are established based on the difference questions previously identified in the methodology chapter. These null hypotheses were developed for the difference questions derived from the last research question only. These hypotheses were tested via a one-way ANOVA strategy. The remaining research questions were explored using frequency and content analysis of the various data sources as previously discussed.

3. ANOVA Tests

In the third section, ANOVA tests, the parametric statistic known as one-way ANOVA was used to test the difference null hypotheses to assist in answering the final group comparison research questions.

4. Phone Interviews

The fourth section, phone interviews, presents a summary of the data obtained through seventeen phone interview surveys. This data collection tool was used to collect data not easily captured through the web survey.

5. Interviews with Past and Present Managers

To get a historical, managerial perspective phone and face-to-face interviews were conducted during the course of this research project with past and present LMDSS managers. A summary of these findings is contained in the final section of this chapter.

B. FREQUENCY AND CONTENT ANALYSIS

1. Demographics

The two IVs considered in this thesis are the user categories and the various organization types. User category demographic data will be referred to as IV-1 and the organization type as IV-2.

The user category groups (IV-1) were broken into four subsets: Officer, Enlisted, General Service (GS) and Civilian. IV-1 demographic data was obtained through the use of the original NAVAIR LMDSS user database. A result of the breakdown of the respondents is displayed below in Table 6.

Group Name	Number of Responses	Percentage of 152 Respondents
Officer	14	9%
Enlisted	25	16%
General Service	74	49%
Civilian	39	26%
Total	152	100%

Table 6 User Category Groups (IV-1) Summary Results

The organization type was obtained through direct input by the survey respondents. The resulting organizational categories are listed in Table 7. The data found in Table 7 shows a majority of the responses came from survey members attached to system commands, civilian firms under contract to the Navy, and depots. A total of 65 percent of the total survey response data was received from personnel in these three organization types. The two organizations, whose members did not reply to the survey, Commander Naval Reserve Force (COMNAVRESFOR) and the Naval Safety Center, were automatically deleted from this and all following histograms to facilitate easier analysis. A reason for the non-response from users within these two commands is not known.

Organization Type	Number of Responses	Percentage of 152 Respondents
Systems Command (COMNAVAIRSYSCOM, SPAWAR...)	40	26 %
Civilian Firm under contract to the Navy	36	24 %
Depot	23	15 %
Other	14	9 %
Wing	9	6 %
Squadron	7	5 %
Aircraft Intermediate Maintenance Dept.	6	4 %
Type Command (COMNAVAIRPAC, COMNAVAIRLANT...)	5	3 %
Marine Corps Activity	5	3 %
Fleet Command (CINCLANT, CINCPAC, COMTHIRDFLT...)	3	2 %
COMNAVAIRRESFOR	2	1 %
Navy Inventory Control Point	2	1 %
Naval Safety Center	0	0 %
COMNAVRESFOR	0	0 %
Total	**152**	**100 %**

Table 7 Organization Type Groups (IV-2) Summary Results

2. Frequency of Use

Survey questions 1, 3 and 4 as found in Appendix D are covered in this section. For ease of use, each figure in this chapter containing a percentage histogram also displays the specific question as asked in the original survey.

Figure 3 displays the percent histogram for question 1, "How often did you access LMDSS when it was available on the web?" It shows less than 15 percent of all responding users accessed the LMDSS program on a daily or weekly basis. Over 41 percent used the application infrequently and 26 percent answered Not Applicable. This may partially be attributed to the long period of time that the program was frozen. New users were still being issued passwords but were unable to access the system.

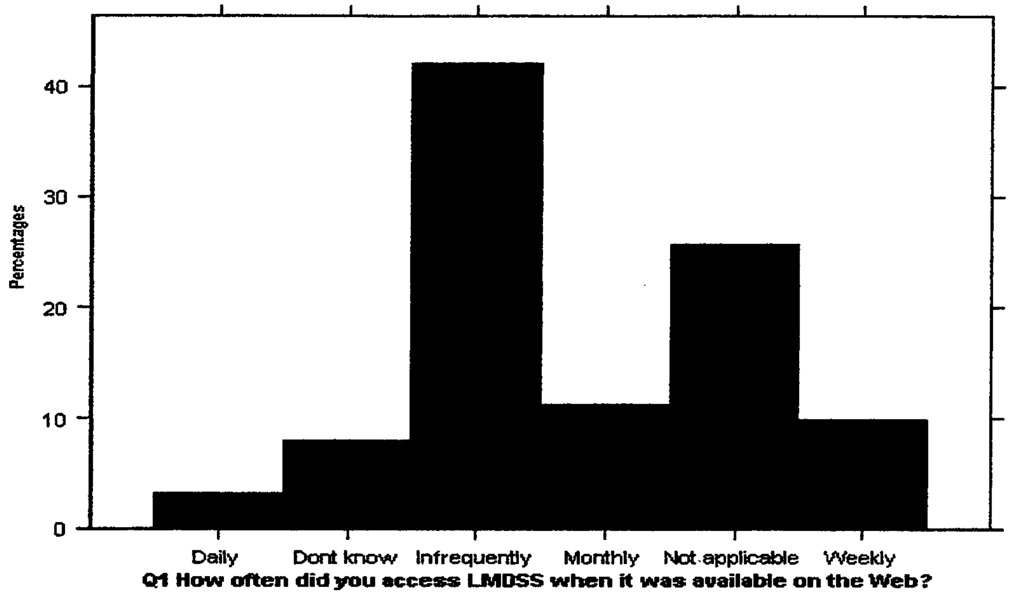


Figure 3 Frequency of Usage Percent Histogram

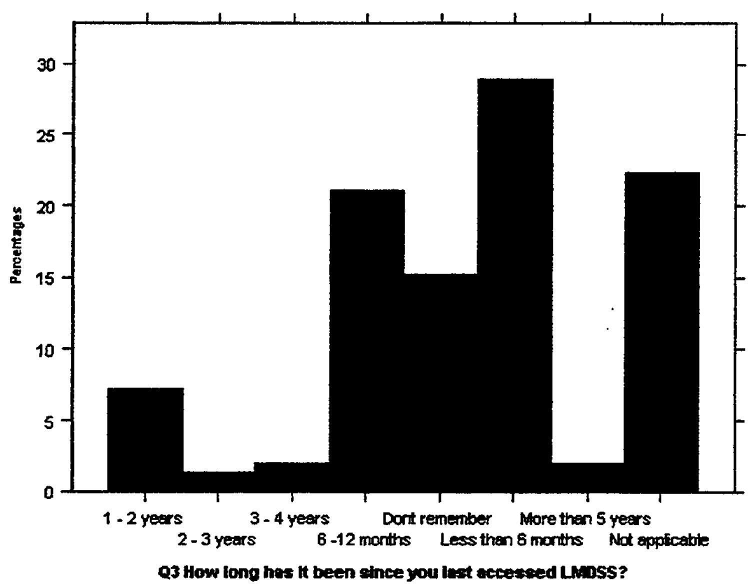


Figure 4 Duration Since Last Access Percent Histogram

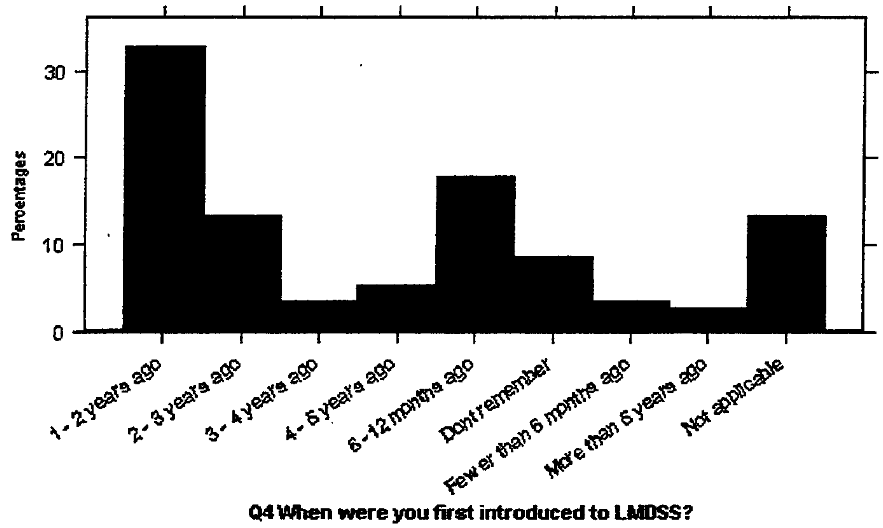


Figure 5 Length of Time Using LDSS Percent Histogram

Questions 3 and 4 are directly related to each other and are covered in Figures 4 and 5. Question 3 asked, "How long it has been since you last accessed LMDSS?" and question 4 queried, "When were you first introduced to LMDSS?" From Figure 5, it is apparent that over half of the users signed onto the system in the last two years yet only 6 percent of respondents have signed on in the last six months.

3. Hardware/Software Concerns

Results of questions 5 through 8 are discussed in this section. Figure 6 indicates the findings of question 5, "When the LMDSS Web site comes back online, what will be your primary means of accessing it?" As shown by the percent histogram, nearly 60 percent of all respondents reported they accessed LMDSS through the network.

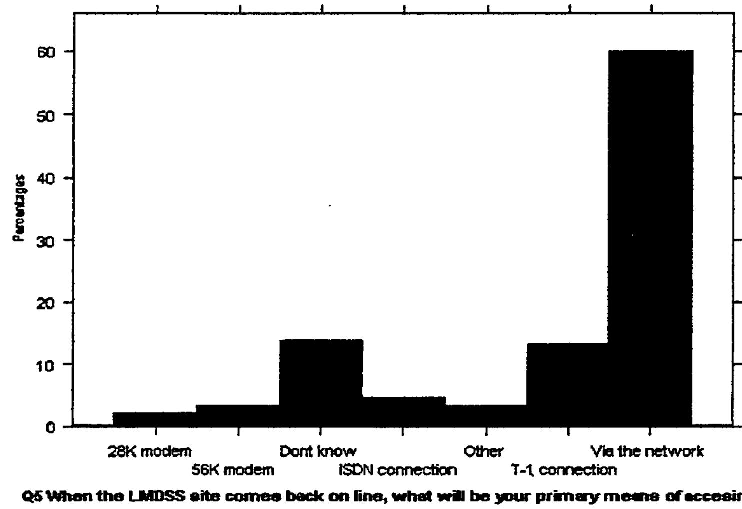


Figure 6 Primary Means of Access to LMDSS Percent Histogram

Question 6 asked the respondent to check all answers that applied to the following question: "What kind of problems did you have accessing LMDSS?" Results are tabulated in Table 8.

Answer	Number of Responses	Percentage of 152 Respondents
I have not had any problems	51	33 %
Don't know, just could not access the LMDSS web site	32	21 %
Other	32	21 %
Firewall blocking access	23	15 %
Downloading matrix tables	19	12 %
Unable to access the IQ tool	11	7 %
Computer hardware inadequate	10	7 %
Internet browser issues	8	5 %
Proxy difficulties	6	4 %
Total without difficulties:	**51**	**34 %**
Total with one or more difficulties	**101**	**66 %**
Total with two difficulties	**17**	**11 %**
Total with three or more difficulties	**11**	**7 %**

Table 8 Type of Access Difficulties Table Summary

It should be noted that although 101 people reported at least one difficulty, only twenty-eight reported encountering more than one difficulty. On the other hand, forty-two percent of the respondents responded with "don't know" or had some "other" type of problem. Without knowing the experience level of the users and the specifics of their inability to access the site, it is impossible to determine exactly what type of difficulty these respondents encountered. They may have encountered unique problems or they may simply have been unable to identify the problem.

Table 9 presents the cross tabulation summary statistics between IV-2 (organization type) and the type of difficulties encountered by the surveyed users. It is interesting to note that civilian firms appeared to encounter firewall difficulties at a greater rate than their government counterparts. Twenty-five percent of all civilian contractors surveyed and nearly twenty-two percent of all depot respondents reported firewall trouble. Systems commands, which were the largest of the surveyed organizations, also reported firewall difficulties but at a much lower rate of 7 percent.

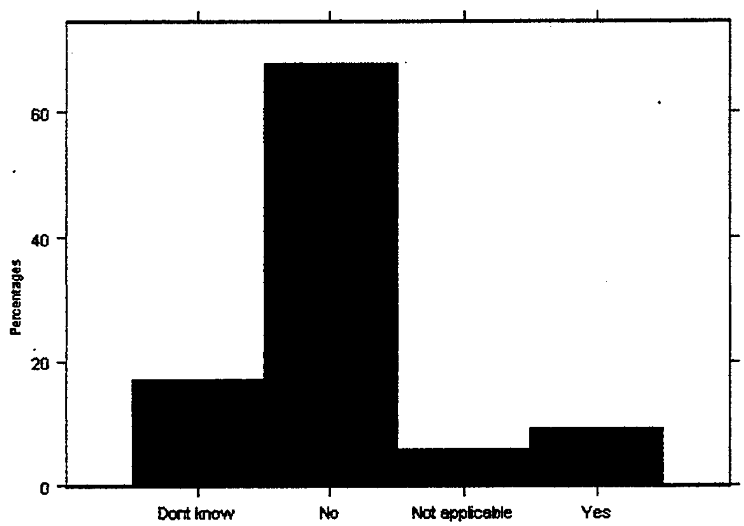
Type of Difficulty and Total Number		Top Three Organizations and Number of Difficulties per Organization					
Firewall	23	Civilian Firm	9	Depot	5	SYSCOM TYCOM	3
Downloading matrix tables	19	Civilian Firm	6	Depot	5	Wing	3
Unable to access the IQ tool	11	Depot	4	Civilian Firm	3	Wing	3
Computer HW inadequate	10	Depot	4	AIMD	2	USMC	1
Internet browser	8	USMC	2	Civilian Firm	2	NA	
Proxy	6	Civilian Firm	3	Depot	2	TYCOM	1
Other	32	SYSCOM	11	Civilian Firm	7	USMC Other Depot	3
Don't know	32	Civilian Firm SYSCOM	9	Depot Other	5	NA	

Table 9 Summary of Access Difficulties by Type Organization

In addition to the firewall access problem, a lot of users answered with "other" or "don't know". Not surprisingly, the three organizations that comprise the largest percentage of the total survey respondents (systems commands, civilian firms and depots) reported the largest number of "other" and "don't know" responses.

Although the systems commands provided the greatest number of respondents, many of the more specific access problems were identified by the depot level users who lodged a greater quantity of complaints. Part of this might be attributed to the fact that depot users provided the largest number of complaints concerning inadequate computer hardware. There may be a correlation between inadequate hardware and the access problem but further study would be required.

Question 7 asked, "When LMDSS is back online, users will be required to use Netscape Communicator 4.5 with 128 bit encryption. Do you anticipate any problems downloading and installing this browser?" Figure 7 presents the results of this question.



Q7 When LMDSS is back online, users will be required to use Netscape Communicator 4.5 with 128 bit encryption (available for free download at www.netscape.com). Do you anticipate any problems downloading and installing this browser?

Figure 7 Browser Installation Percent Histogram

As shown in this question result, there does not seem to be any anticipated difficulty in the change of browsers.

Question 8 was an open-ended question that queried users on "What type of software problems did you experience while using LMDSS?" Table 10 summarizes the results of this query.

Category	Number of Responses	Percentage of 152 Respondents
Not Applicable	95	63 %
No Problems	30	20 %
Entered comment	27*	18 %
Never used LMDSS	5	3 %
Left completely blank	2	1 %
** Seven users who reported no problems also entered comments.*		

Table 10 Summary of Respondents Reporting Software Problems

Although only 17.8 percent of all respondents entered comments about the problems they experienced while using the LMDSS application, many of those who did reply entered multiple areas of concern. Several themes of dissatisfaction were easily identified because they were repeated throughout the commentary. The top five concerns raised in the dialog from the question 8 submissions were as follows:

- Inability to access LMDSS
- LMDSS was not easy to use
- Report generation was not available
- Data was not available or unreliable
- Netscape vs. Explorer

Below are some of the more insightful comments on the aforementioned top five concerns. These comments do not necessarily reflect the opinions of the authors and are recorded as depictions of the beliefs of the survey respondents.

On the inability to access LMDSS, several reasons for the difficulties were listed but the next two comments best characterize the major difficulties encountered.

> Just couldn't access [LMDSS]. When I did it stated 'Server Down' or another time it said that LMDSS was in the middle of moving...Referred me to yet another site and it stated it was not available...
>
> Civilian Firm - Senior Systems Analyst

> FIREWALL! Could not fully access LMDSS when working off-base.
>
> Civilian Firm - Analyst

On the ease of use, the comments varied from specific to broad in scope. The three examples below provide a sense of the overall picture.

> Too difficult to gain and maintain access for occasional users. If you don't use it frequently, you end up not being able to use it at all.
>
> USMC - LTCOL ASL-33

> Navigation to the screens I was interested in was NOT intuitively obvious. By obvious, I mean that a relatively inexperienced user could not locate the correct link (page) with the first quick scan edit. I was looking for SALTS information.
>
> Systems Command-NAVAIR Logistics Info Systems Engineer

> ...The method of data extraction and the flexibility of output data format are no match for the current NALDA/ECA output.
>
> Civilian Firm - Engineer

On report generation, several systems command personnel complained that advertised report functions were not available. One gentleman from a helicopter wing not only had difficulty using the canned reports, but had greater difficulty trying to use the IQ tool. He wrote:

> Although I attended the IQ class here at NAS North Island from a billet assigned by AIRPAC, I was never able to get the IQ program to work. Contacted CNAP personnel and they were having the same problems. The support at PAX River provided by (*name withheld*) was useless at the time also. So I just gave up until it is fixed. I do need it and reverted back to doing reports from the old NALDA and TDSA databases....
>
> Wing - Configuration Manager

Other personnel reported they did not use LMDSS in the past due to the unavailability of data for certain aircraft type or components or that data they did receive was unusable due to unreliability or incompatibility with older systems.

Lastly, on Netscape versus Explorer, although question 7 results indicated that there is little anticipated difficulty foreseen in getting and installing the required browser, there are still some questions about the decision itself. Some respondents questioned the reasoning behind the move to use Netscape. One squadron maintenance Chief with extensive computer experience wrote this statement:

> I'd note here that the above requirement for Netscape is poor headwork. Put aside that it is not in keeping with the IT-21 "Standard" that has been endorsed by CINCLANT and CINCPAC...it becomes an administrative and logistical burden to marry oneself to a particular browser." Squadron Data Analyst

4. Usage of Application

This section focuses on how the respondents have used LMDSS in the past and how they intend to use the application in the future. The survey questions that will be analyzed in this section include questions 9-14, 16, 18-19, and 35-37. Questions that affect the IQ tool will also be covered here.

The first two questions in this section were open-ended. This was an intentional tactic on the part of the authors to illicit unbiased responses reflecting what the users actually want from the LMDSS program. Although a list of choices would have been easier to tabulate, it is limiting in nature. Question 9 was, "What kind of information do you expect to retrieve from LMDSS when it becomes available?" Table 11 summarizes the respondents' entries on this question.

Comments received from this question were more difficult to analyze and categorize than previous questions due to the extreme range and variety of submitted answers. As before, many responded in vague generalities while other responses

precisely explained what types of data they desired to receive from LMDSS. Seventy-nine users entered comments for this question. Many of the comments contained more

Category	Number of Responses	Percentage of 152 Respondents
Entered comment	**79**	**52 %**
Don't Know	43	28 %
Not Applicable	26	17 %
Do not intend to use LMDSS	2	1 %
Left completely blank	2	1 %

Table 11 Summary of Respondents' Expectations About LMDSS Information

Comment Categories	Number of Responses	Percentage of 152 Responses
Component and engine failure histories	17	11 %
Reliability and maintainability data	11	7 %
Detailed cost analysis data	11	7 %
All 3M data for all naval aircraft	9	6 %
ID of major reliability degraders	7	5 %
Top readiness degraders	7	5 %
Trend analysis data	6	4 %
Historical maintenance man-hour data	5	3 %
Repairable histories	5	3 %
Flight hour summaries	4	3 %
Technical directive status information	4	3 %
All data currently available in NALDA I	4	3 %
Cross reference tables for WUC, P/N, NIIN, UIC	3	2 %
Historical SRC data	2	1 %
Support equipment historical data	2	1 %
Complete engine histories	1	1 %
Drill down to JCN level	1	1 %
Cannibalization historical data	1	1 %

Table 12 Summary of Respondents' Comments About Information Available from LMDSS

than one desired type of information. Table 12 provides a frequency breakdown of the user requested information type categories.

When available, the command organization and job title were included from the respondent database to provide insight into why these specific requests were made. These comments are not all inclusive but were representative of the sample. Some specific comments received from the responses to this question are listed below:

> Cannibalization data, supply data, NMCS/PMCS data.
> Wing - Data Analyst
>
> Would like to track failure and removal data for existing systems and new system applications during initial installation and subsequently as a fielded system.
> Systems Command - PMA Data Analyst
>
> Failure data of a particular part number. Hopefully this information will help me decide if we want to open up an engineering investigation when a failure is reported by the Fleet.
> Depot - Data Analyst
>
> Primary concern is failure data as it relates to Depot repair.
> Systems Command - NAVAIR Data Analyst

Question 10 asked, "What information do you require but are unable to access via LMDSS?" Table 13 summarizes these results.

Category	Number of Respondents	Percentage of Respondents
Don't Know	71	47 %
Not Applicable	44	29 %
Entered comment	**34**	**22 %**
Left completely blank	3	2 %

Table 13 Summary of Respondent's Requirements from LMDSS

Fewer people answered this question than the previous one. Referring back to Figure 3, the Frequency of Usage percent histogram, only thirty-seven out of 152 respondents reported using LMDSS on at least a monthly basis. It is not unexpected therefore to find that a large percentage of users do not know what LMDSS can and

cannot provide. The length of time LMDSS has been inoperable is also a contributing factor toward the low response rate for this question. Numerous statements reflected the fact that LMDSS was not fully functional nor were its exact capabilities well known by the users. Some items requested by the users responding to the web survey are already incorporated into LMDSS such as:

- Historical data by part number for all Navy Aircraft
- Current Aircraft Inventory Records for specific type aircraft
- OP-20 Data, AH-1W Maintenance Data, UH-1N Maintenance Data

Others requested data that is currently contained in other portions of the NALDA system. For example: "Info available on NALDA I ECA report 733" was one comment. Still others were unclear on whether LMDSS would have the correct capability but made suggestions on what information they believed was needed. Due to the variety of the requests, categorization by subject was not possible. Below are some of the more articulate comments in random order:

> We need failure information at the serial number level with the JCN linked to depot data showing the actual repair done. Also need link to aircraft configuration information showing the number of cycles (hours, landings, etc) that the component lasted between last repair and failure.
> Depot - R&M engineer

> Work Unit Code (WUC); NIIN Cross reference top degraders by cost reliability and supportability mean time between failures (MTBF) for WSC (Actual and Predicted) cost of maintaining WUC service record card information. USMC - Depot Logistics Management Specialist

> I sure could use real time AIMD engine inductions and current status. Also real time bare firewalls. Although AEMS gives me this info, I would like one central database. Maybe LMDSS already does this, but only a few engine areas were up and running.
> Type Command - COMNAVAIRRESFOR PP Logistics Manager

History on components, aircraft, engines. Data to use as analytical processes to determine extent of work within the depot. Review RCM data throughout the responsible commands in the DMD reporting chain.

Depot

Haven't been able to sort or select by unit identification code (UIC) or command, Secondary data: Type-Model-Series (TMS) of aircraft, work center, WUC, labor hours, beyond capability of maintenance (BCM) hours, etc...

Fleet Command - CINCPACFLT Manpower analyst

I would like to have information on the current state of the Naval Aviation Fleet in terms of: corrosion, fatigue, cracking, engine failures, accidents, corrosion prevention programs...

Systems Command - NAWC Electrical Engineer

Cost per flight hour, mean time to replace with valid metrics (PMB issue), mean time between failures with valid metrics (PMB issue)

Type Command - COMNAVAIRPAC

Question 11 asked, "How difficult was it to build matrix tables within LMDSS?" The question was done in a five-point interval Likert type scale with a score of one identified as "impossible" and a score of five being classified as "easy". Results are shown in Figure 8. All Likert formatted questions are displayed in three dimensional graphs.

As shown in Figure 8, the majority of the respondents answered Not Applicable. This could be attributed to the fact that the LMDSS program had not been on line for a while or that the users had not used the tool to build matrix tables. This could also be an indicator that more training needs to be conducted on this aspect of LMDSS' capabilities. The results of those who did respond are tabulated in Table 14.

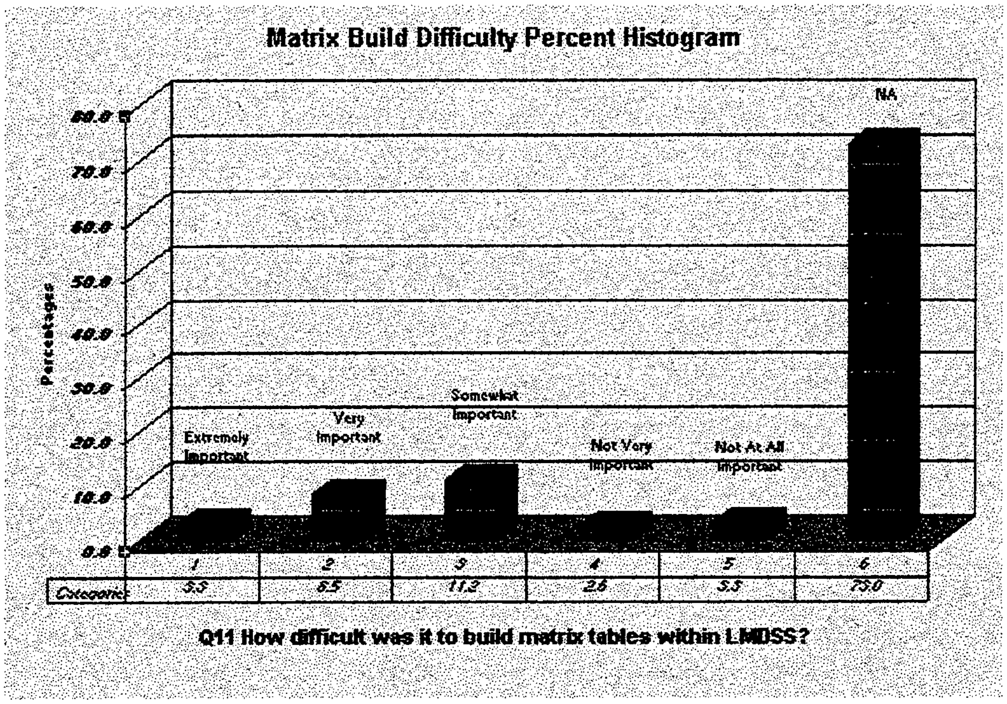


Figure 8 Matrix Build Difficulty Level Percent Histogram

Category	Number of Responses	Percentage of 41 Respondents who Answered
1 Impossible	5	12 %
2	13	32 %
3	17	42 %
4	4	10 %
5 Easy	2	5 %
Total who answered	41	

Table 14 Matrix Build Difficulty Likert Results

Most people responded to this question by answering in the middle of the five point Likert scale but more tended to lean towards difficult than easy. Fewer than five percent of those who answered selected “easy”.

Question 12 asked the respondent to check all answers that applied to the following question, “Which LMDSS modules did you access the most?” Results are tabulated in Table 15.

Answer	Number of Respondents	Percentage of Respondents
Trend Analysis	51	34 %
Not applicable	48	32 %
Cost Analysis	37	24 %
Management Analysis	36	24 %
Supply Analysis	34	22 %
Reference Information	29	19 %
Detailed Analysis	29	19 %
Engine Analysis	28	18 %
Candidate Identification	23	15 %
Don't know	17	11 %
Application Management Tools	10	7 %
Change Requests	6	4 %
Other	6	4 %
Feature Synopsis	2	1 %
Total who used at least one area	**87**	**57 %**
Total who Don't know or NA	**65**	**43 %**

Table 15 Type of Access Difficulties Table Summary

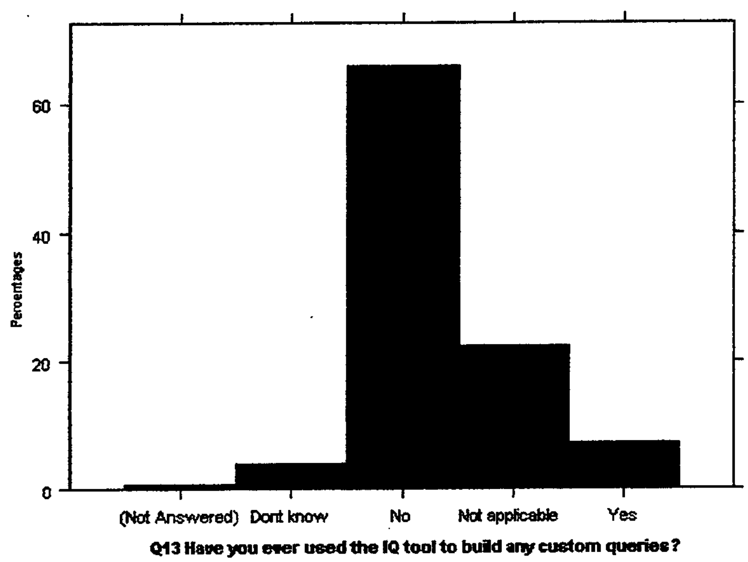


Figure 9 IQ Tool Usage Percent Histogram

The next three questions to be analyzed, questions 13, 14, and 16, all focus on the IQ tool. Question 13 was a straightforward question that asked, "Have you ever used the IQ tool to build any custom queries?" Results are shown in Figure 9. As displayed in the percent histogram, the majority of users had not used the IQ tool. Only eleven people surveyed (7 percent) reported using the IQ tool.

Question 14 asked "Do you think the IQ tool was user friendly?" This question had a total of sixteen respondents (11 percent) answer with a yes or no response and the

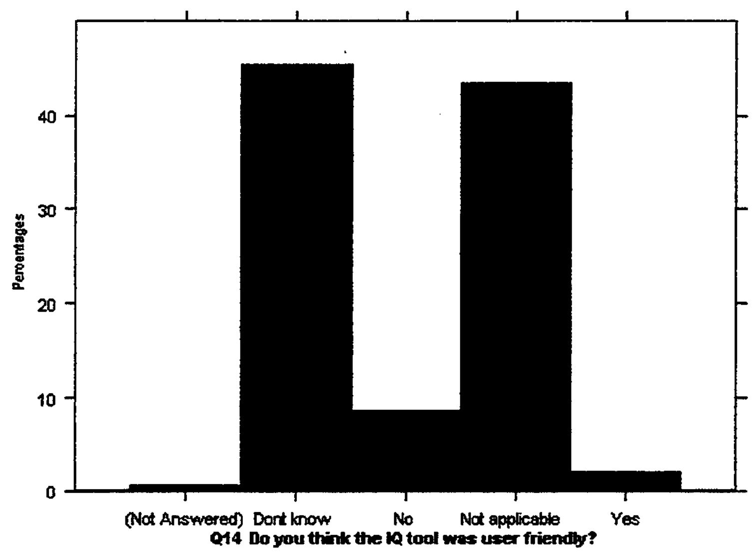


Figure 10 User Perceptions of IQ Tool's Ease of Use Percent Histogram

results are shown in Figure 10. Only two percent of the IQ users felt the tool was friendly.

Question 16 differs from the two previous questions in that it asks about the users' beliefs on the importance of including an IQ tool within the LMDSS application. Question 16 asked, "How important do you consider the addition of a structured ad hoc query tool to LMDSS?" Results are included in Table 16. Figure 11 displays the percent histogram for question 16.

Category	Coding	Number of Responses	Percentage of 152 Respondents
Extremely Important	1	35	23 %
Very Important	2	45	30 %
Somewhat Important	3	20	13 %
Not Very Important	4	1	1 %
Not At All Important	5	0	0.0 %
Don't Know, NA	NA	51	34 %

Table 16 Importance of IQ tool to LMDSS Responses and Recoding Criteria

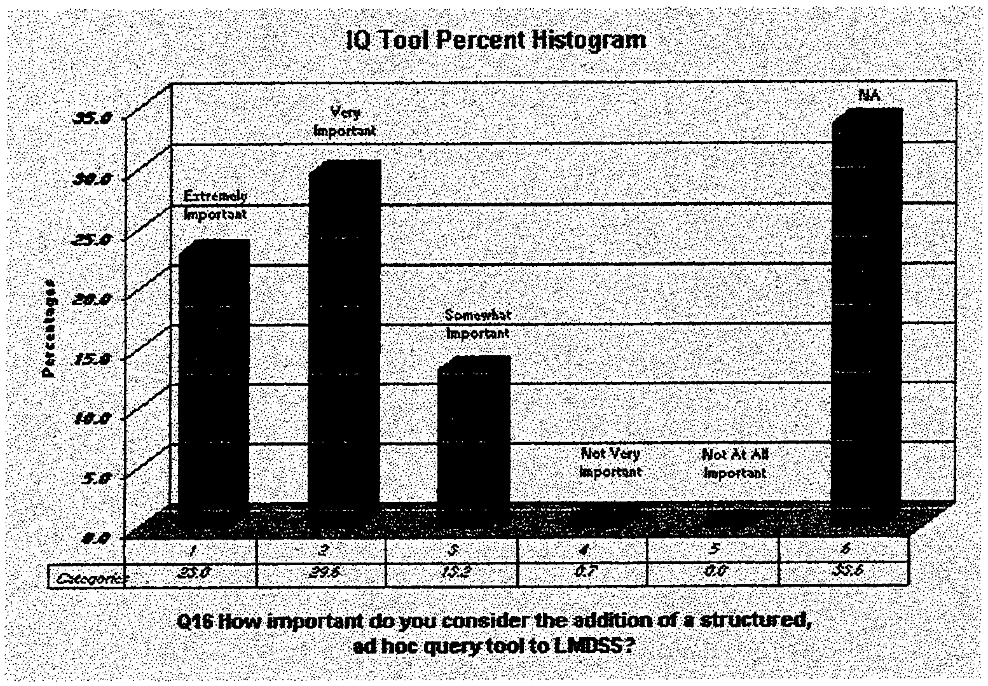


Figure 11 Importance of IQ Tool Percent Histogram

The majority (53 percent) of respondents declared the addition of an IQ tool would be "extremely" or "very important". This is an interesting finding in light of the fact that only two percent of the respondents said that they found the existing ad hoc query tool easy to use in question 14 (Figure 10) and less than ten percent of the respondents stated they had accessed the existing tool in question 13 (Figure 9).

Question 18 asked, "Please list a few of the key decisions you would like LMDSS to support when it comes back online." This open-ended question was designed to focus

on the type of major decisions LMDSS needs to support. Most users described the type of information they required instead of describing the key decisions as requested. Table 17 summarizes the results of this query.

Category	Number of Responses	Percentage of 152 Respondents
Don't Know	63	41 %
Not Applicable	51	34 %
Entered comment	**39**	**26 %**
Left completely blank	3	2 %

Table 17 Summary of Respondents' Recommendations on LMDSS Key Decisions

Due to the large variety of answers, categorization of this data was not practical. Four insightful comments listed below are representative of the collected results.

> Life cycle cost decisions, reliability centered maintenance decisions, integrated maintenance concept decisions, affordable readiness decisions, defense systems affordability decisions, supportability issues, acquisition issues, etc...
>
> Depot - Mechanical Engineer/Data Analyst

> Create some simple tool to show, in plain language, the present support status of a given item. One page with cost, AVDLR, items on hand, items due in, quarterly demand, number of maintenance actions at Organizational and/or Intermediate level for the most recent twelve months, and number of A-799s within those maintenance actions should give the typical user (and his/her novice level management audience) the sufficient data to make educated decisions.
>
> Depot - Electronics Engineer

> Part number usage and part number cost of ownership (how much does it cost to maintain a part number over a specified time).
>
> Civilian Firm

> Is end item experiencing infant mortality or wear out failure modes? How many cycles did the unit operate before failure? What was the specific failure mode? Is it worthwhile to invest in reliability improvements to a given end item (need cost and configuration data)
>
> Depot - R & M Engineer

Question 19 asked, "LMDSS will collect much of its raw data from NALCOMIS. If there is any data you will require which is not captured by NALCOMIS, please describe it." Table 18 displays the summarized results.

Category	Number of Respondents	Percentage of Respondents
Don't Know	65	43 %
Not Applicable	56	37 %
Left completely blank	3	2 %
Entered comment	**28**	**18 %**

Table 18 Summary of Respondents' Items not covered in NALCOMIS

Many comments in this section reflected a lack of knowledge about the data available for retrieval within LMDSS. A few comments referred to items not currently available within the LMDSS application. The other comments included such topics as:

- Increased supply statistics
- Support equipment data Technical Directives Library Configuration Control information
- Government On-line Data System (GOLD)

In general, most respondents appeared comfortable with the data provided by the Naval Aviation Logistics Command Management Information System (NALCOMIS), provided the databases and the matrices were properly formatted and accurate.

Question 35 asked, "What might some of your reasons be for using LMDSS when it returns to the web? (Check all that apply)". Results are displayed in Table 19.

Question 36 was an open-ended question which requested users to clarify their definitions if they checked the "other" category in question 35. Of the fifteen people who selected "other" in question 35, only ten entered comments. Three of the responses mentioned manpower calculations. Other selections are listed below:

Answer	Number of Responses	Percentage of 152 Respondents
Conduct Trend Analysis	115	76 %
Reliability information	104	68 %
Identify system degraders	100	66 %
Identify high cost drivers to conduct cost analysis	91	60 %
Find data to support logistics acquisition decisions	89	59 %
Search for data to complete periodic reports and forms	77	51 %
Track the result of implemented improvements	76	50 %
Drill down to the MAF level to determine cause of system degraders	73	48 %
Reduce life cycle support costs of aviation systems	72	47 %
View cost data and flight hour history of aircraft engines	68	45 %
Measure the impact of decisions or policies on platform readiness	61	40 %
Measure the effect of improvement actions on support costs	61	40 %
Compare the performance of my command with similar commands	34	22 %
Other (Please describe in question 36 only)	15	10 %
Completely Blank Entries	**6**	**4 %**
Users who completed at least one block	**146**	**96 %**

Table 19 Users Reasons for Using LMDSS

Once again the reasons for using LMDSS justify the need for data analysis to review raw data and summarize info into a usable format for the APML.... Otherwise we will expend an awful lot of time on data that may conflict with other decision-making systems.

Systems command - DAPML

Get detailed failure mode information at the serial number level. Get depot data linked by Job Control Number (JCN) to maintenance action form (MAF). Get operating cycles information at the serial number level.

Depot - R& M Engineer

Review historical hours and workload / backlog to assist in determining billet requirements for a commands Activity Manning Document.

Fleet command - CINCPACFLT Management Analyst

... I have had logistics people collect failure data of a particular part number to help in my decision to open up an engineering investigation on the failed item.

Systems command

Question 37 asked, "Referring to your answers in questions # 35 and # 36, what do you anticipate your primary reason for using LMDSS will be?" Results for this question are included in Tables 20 and 21. On this question some users repeated choices listed in questions 35 or 36 while others provided unique answers. Some of the replies from question 37 were:

Category	Number of Responses	Percentage of 152 Respondents
Entered comment	**79**	**52 %**
Don't Know	43	28 %
Not Applicable	26	17 %
Do not intend to use LMDSS	2	1 %
Left completely blank	2	1 %

Table 20 Summary of Respondents' Expectations About LMDSS Information

Depends on training. Time, workload, and specialization are drivers. If training is intense and concentrated, i.e. short term and Frequently Asked Question (FAQ)/Help functions are improved, the primary reason for use will be to assist in the acquisition logistics determinations AND monitor those decisions in sufficient detail to allow for change before change becomes too costly.

Systems Command - APML

Since I have no data analysis support I would think this system if accurate could be of great benefit in managing my engine program on a day to day basis.

Systems Command - Engine DAPML

Long-term analysis and development of improved analysis techniques (in particular, studying predictive indicators, similar in purpose to the Emergent Problems Matrix).

Systems Command - Logistics Management Specialist

...developing composite systems for comparative analysis, verifying system performance and cost once new acquisition is fielded.

Other - ILS manager

Answer	Number of Responses	Percentage of 152 Respondents
Conduct Trend Analysis	20	13 %
Reliability information	20	13 %
Identify system degraders	18	12 %
Identify high cost drivers to conduct cost analysis	15	10 %
Reduce life cycle support costs of aviation systems	13	9 %
Track the result of implemented improvements	9	6 %
Measure the impact of decisions or policies on platform readiness	9	6 %
Aircraft Engine Data	7	5 %
Find data to support logistics acquisition decisions	6	4 %
Technical Support/TD compliance	5	3 %
Daily Management	5	3 %
Support the Fleet	5	3 %
Drill down to the MAF level to determine cause of system degraders	4	3 %
Search for data to complete periodic reports and forms	4	3 %
Measure the effect of improvement actions on support costs	4	3 %
View cost data and flight hour history of aircraft engines	3	2 %
Parts Availability/Tracking	3	2 %
Compare the performance of my command with similar commands	2	1 %

Table 21 Primary Reasons for Using LMDSS

Measure the effect of improvement actions on support costs. This is vital to the Depots in reducing cost and continuing to produce a quality product.

Depot - Maintenance Data System Coordinator

5. Modeling and Simulation

This topic was covered in survey questions 20 and 21. The former question was a Likert scale formatted question that requested the user to determine "How important do

Category	Coding	Number of Responses	Percentage of 152 Respondents
Extremely Important	1	17	11 %
Very Important	2	26	17 %
Somewhat Important	3	30	20 %
Not Very Important	4	7	5 %
Not at All Important	5	2	1 %
Don't Know, NA	NA	70	46 %

Table 22 Importance of Modeling/Simulation Capabilities

you consider the development of a modeling/simulation capability in future versions of LMDSS?" Table 22 and Figure 12 demonstrate the results of this question.

From Table 22, it is obvious that nearly half of the users answered "don't know" or "not applicable". The majority of those who did voice an opinion were in favor of further development of modeling and simulation capabilities. This question yielded a much higher response rate than the similarly formatted question 11, Figure 9, which was based upon the IQ tool. This suggests a greater familiarity of modeling/simulation techniques among users than knowledge about the use of IQ tools.

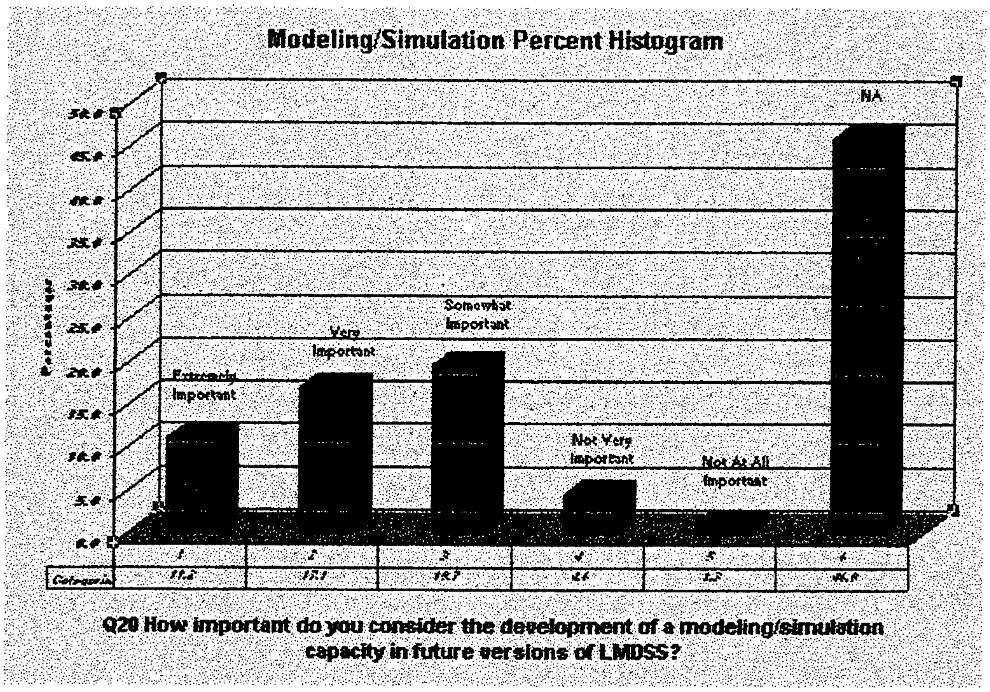


Figure 12 Modeling/Simulation Percent Histogram

Category	Number of Responses	Percentage of 152 Responses
Not Applicable	61	40 %
No	59	39 %
Entered comment	**17**	**33 %**
Don't Know	8	5 %
Did not reply	7	5 %

Table 23 Response Summary for Model/Simulation Examples

Question 21 asked, "Can you provide an example of how a modeling/simulation capability to conduct sensitivity (what if) analysis will be useful?" Table 23 provides a frequency breakdown of the users who provided examples of modeling/simulations that would be useful. Many of the comments contained more than one example. The specific types of examples are categorized and displayed in Table 24.

Comment Categories	Number of Responses	Percentage of 152 Responses
Predict future manpower and repair requirements and how they are affected by flight hour levels	8	5 %
Impact of A799 removal levels on readiness	3	2 %
Estimating life cycle costs and impacts of aging	2	1 %
Compare Intermediate level costs to Depot level costs	2	1 %
Determine return on investment for proposed readiness and maintainability program changes	2	1 %
Forecast spare costs and failure trends	2	1 %
Justify Reliability Centered Maintenance (RCM) and Engine Change Proposal (ECP) analysis	2	1 %
Compare historic costs to actual projected costs	1	1 %

Table 24 Summary of Types of Modeling/Simulation Examples

Some of the more pertinent selections received from the responses to this question are listed below:

> For a low cost system like Joint Direct Attack Munitions, compare contractor depot vs. government depot vs. disposable, considering costs for movement, parts availability, labor, etc.... For a low cost container (approximately $600) determine the break point for defining 'reusable', considering costs of movement, repair, labor, materials, disposal, etc.
>
> Civilian firm - Logistics Analyst

> ...perform some type of trend analysis or probabilistic modeling of the factors influencing engine repairs. This would help me build my engine repair requirements for the out-years of the budget.
>
> Fleet Command - Depot Requirements Officer

> ...If annual flight hours increase (or decrease), how many more maintenance man-hours will be required? If cannibalization actions are occurring, how many maintenance man-hours have been expended?
>
> Type Command - Analyst

> Life Cycle Cost Estimating - Sensitivity by changing anticipated flight hour usage. Impacts of aging - Sensitivity to cost increases of maintenance over time.
>
> Systems Command - Operations Research Analyst

We have to determine the trade-off of investment cost versus reliability improvement benefits. A model that would link future projected flight hours to a population of end items would be a very beneficial tool for this type of analysis.

Depot - Readiness and Maintainability Engineer

6. Training

A total of five questions, questions 26 through 30, will be covered in this section. The first one, question 26, requested information on "How would you rate the quality of the LMDSS instruction you have received from NAVAIR personnel?" Results are compiled in Table 25.

Categories	Number of Responses	Percentage of 152 Respondents
Excellent	6	4 %
Good	12	8 %
Fair	5	3 %
Poor	5	3 %
Don't remember	5	3 %
Did not receive training	74	48 %
Not applicable	45	30 %

Table 25 Quality of LMDSS Training

Of the 152 respondents, only thirty-three had definitely received training on the LMDSS system and nearly fifty percent stated they had not had any training on the program.

The next question built on this question and asked, "Did the training include Structured Query Language training using the IQ tool?" Of the thirty-three who received the training, nine answered "yes", fourteen answered "no", and the remainder replied "don't remember". Neither question probed into when the user received training so it is not possible to determine if the respondents who answered "no" took their training before or after SQL training was added to the NAVAIR syllabus.

Question 28 asked the users "Do you feel you will need LMDSS refresher training when LMDSS comes back online?" The majority of the respondents said "yes" (68 percent) with only eleven people answering "no" (seven percent). The remaining thirty-four people (22 percent) checked the "don't know" block.

The following question was developed directly from the focus group that was held at NAVAIR. The focus group participants wanted to know the various levels of importance users assigned to different LMDSS training strategies. Question 29 was a Likert question that asked, "How important is 'hands on' LMDSS training with each student assigned to a computer terminal?" This question did not specify the location of the training or whether the training was to be a classroom environment or one-on-one training. Results are shown in Table 26 and Figure 13.

Category	Coding	Number of Responses	Percentage of 152 Respondents
Extremely Important	1	55	36.2 %
Very Important	2	39	25.6 %
Somewhat Important	3	18	11.8 %
Not Very Important	4	2	1.3 %
Not at All Important	5	1	0.7 %
Don't Know, NA	NA	37	24.3 %

Table 26 Importance of Hands On LMDSS Training

The numbers clearly show that most users place a high degree of importance on hands on training.

The final question in this section was an open-ended question asking, "How can LMDSS training be improved?" A summary of respondents' results is covered in Table 27 and a list of means of improvements is listed in Table 28.

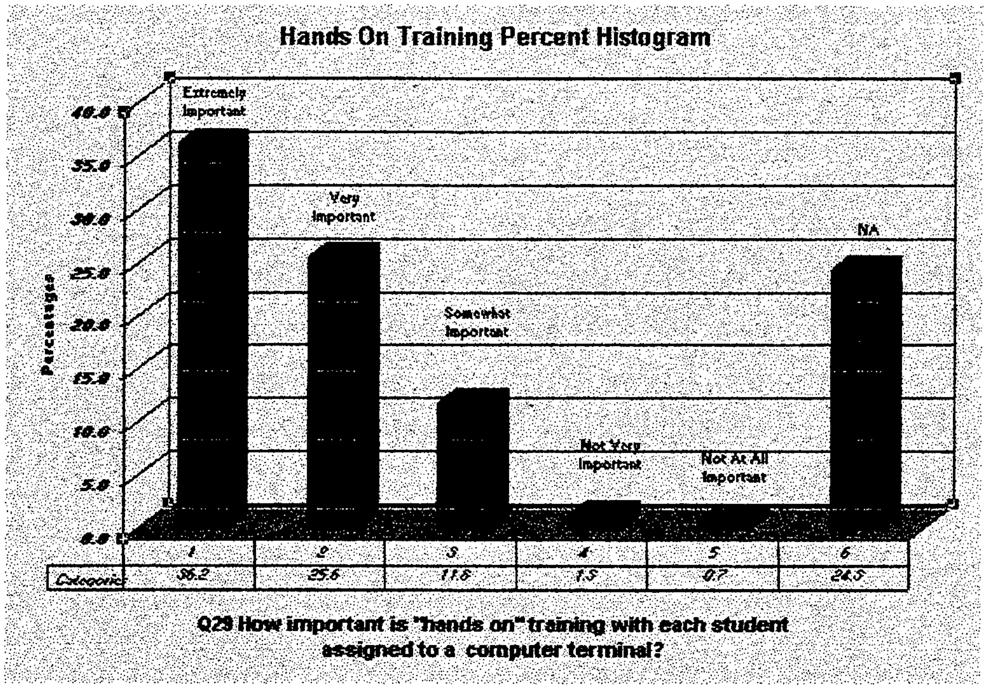


Figure 13 Importance of Hands On LMDSS Training Percent Histogram

Category	Number of Responses	Percentage of 152 Responses
Not Applicable	59	39 %
Don't Know	58	38 %
Entered Comments	**33**	**22 %**
Did not reply	2	1 %

Table 27 Response Summary for LMDSS Training Improvements

All respondents who stated that they had received training entered suggestions on how they would improve LMDSS training. User suggestions are categorized in Table 28. Several people made multiple suggestions within a single comment entry.

Comment Categories	Responses	Percentage of 152 Responses
More hands-on practice sessions with realistic data	13	9 %
Develop an online Web based LMDSS tutorial	12	8 %
Increase training availability to reach more users in a more timely manner	6	4 %
Extend training period to better cover material	4	3 %
Distribute CD-ROM tutorials	4	3 %
Develop two different training courses, one for supervisors and one for data analysts	3	2 %
Develop a more adequate "Help" function	2	1 %
More ad-hoc query training	2	1 %
Expand training to include contractors	2	1 %

Table 28 List of Recommendations to Improve LMDSS Training

Some specific comments received from the responses to this question are listed below:

> .... I have never seen any newsletters as to what is going on with the program as we did when there was just plain NALDA...I feel they have our email addresses and should put out a newsletter as to what is in the works, what some of the problems are, and when we can expect them to be resolved.
>
> Wing - Aircraft Configuration Manager

> LMDSS must be online when training is provided...When I took the class, LMDSS was not ready for us and in fact provided me with a rather negative perspective of its usefulness.
>
> Depot - Data Analyst/Engineer

> ...I was quickly given an introduction to LMDSS during a trip to Patuxent River once, but never received training after getting my user ID and password. Had trouble getting in and eventually gave up trying.
>
> System Command - Program Analyst

> Tailor it for the level of user. As a PMA, I don't anticipate using many of the intricate workings but I want access to check on things occasionally and I want it to be simple enough that I don't become frustrated in the attempt.
>
> System Command - PMA

Additional training in the development and submittal of highly individualized queries.

Civilian Firm -Engineering Support Analyst

7. Graphics

Questions 24 and 32 were developed to determine user concerns about graphical capabilities within the LMDSS program. Both questions were Likert scale questions but each focused upon a different aspect. The first question asked about the development of graphical capabilities within the LMDSS system; whereas, the second question queried the user about the need to develop the means to cleanly export retrieved data to already existing software applications. It should be noted that both of these two questions generated high responses. Question 24 had an 80.9 percent response rate and question 32 received an 83.6 percent rate.

Specifically, question 24 asked, "How important do you consider the development of a graphics capability in future versions of LMDSS?" The results are shown in Table 29 and Figure 14. In question 24, the largest group of users listed internal graphical capabilities as "somewhat important" but more users selected positive responses than negative ones

Category	Coding	Number of Responses	Percentage of 152 Respondents
Extremely Important	1	24	16 %
Very Important	2	32	21 %
Somewhat Important	3	50	33 %
Not Very Important	4	15	10 %
Not at All Important	5	3	2 %
Don't Know, NA	NA	29	19 %

Table 29 Importance of Graphical Capabilities within LMDSS

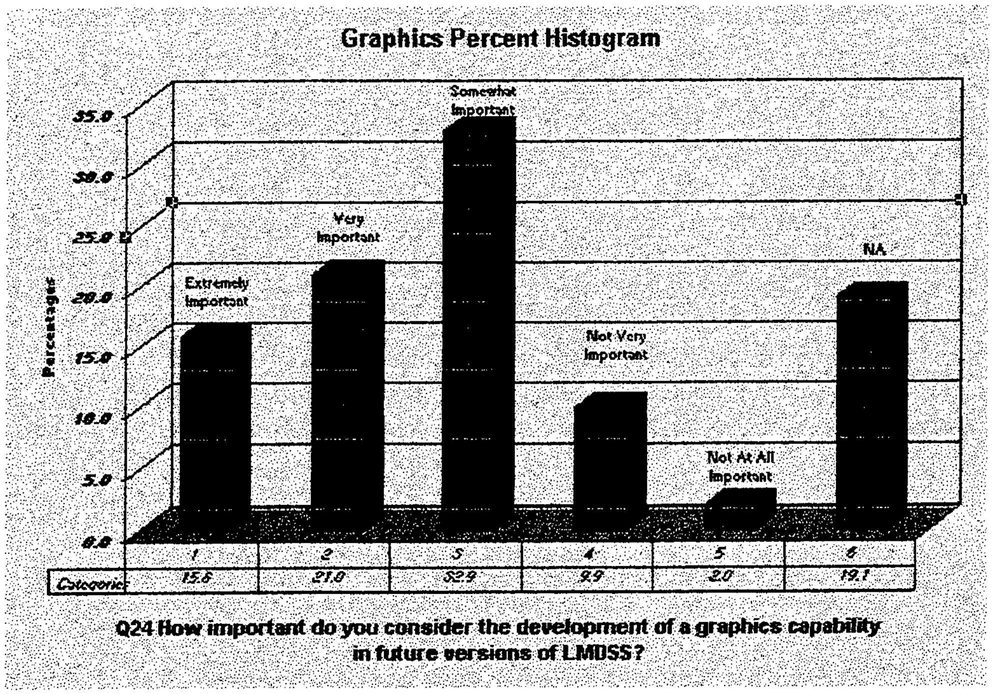


Figure 14 Importance of Graphical Capabilities within LMDSS Percent Histogram

The next question asked, "How important is it for future versions of LMDSS to be able to cleanly export data to applications with graphics capabilities such as Excel?"

Category	Coding	Number of Responses	Percentage of 152 Respondents
Extremely Important	1	61	40 %
Very Important	2	45	30 %
Somewhat Important	3	20	13 %
Not Very Important	4	1	1 %
Not at All Important	5	0	0.0 %
Don't Know, NA	NA	25	16 %

Table 30 Importance of Graphical Export Capabilities

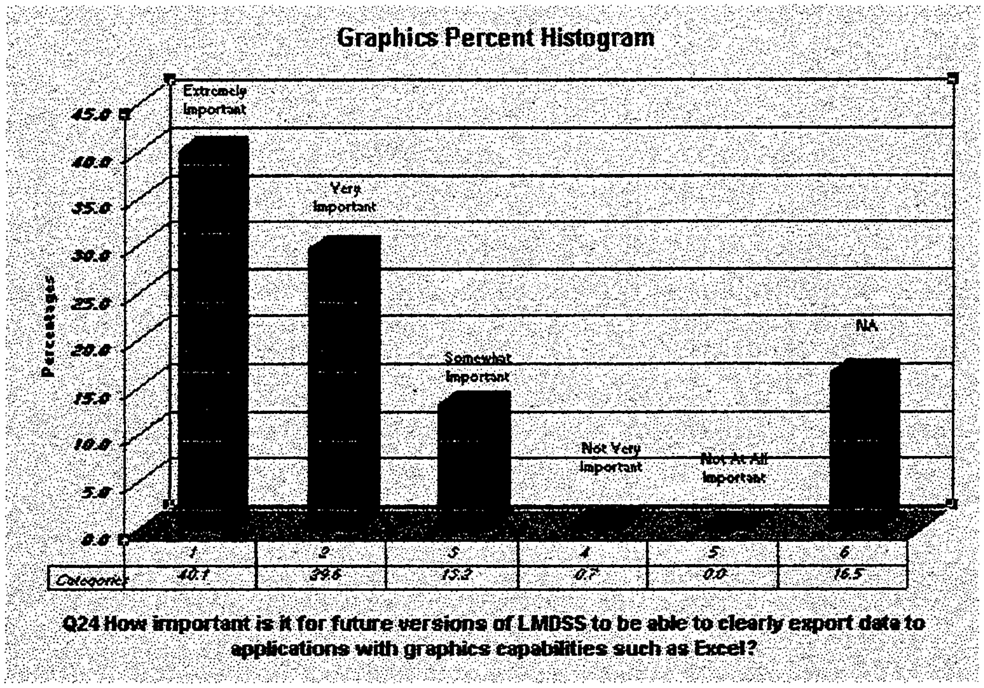


Figure 15 Importance of Graphical Export Capabilities Percent Histogram

This Likert question received the most positive response in the entire survey as shown by the data displayed in Table 30 and Figure 15. Nearly seventy percent of all respondents stated it was extremely important or very important to have good export capabilities to graphical applications.

8. Users' Perceptions about the LMDSS application

This section contains the questions that were perhaps the most difficult to measure and analyze because they did not attempt to collect facts and figures. The questions asked here were used to ascertain the beliefs and perceptions of the users toward the LMDSS system. Since this type of information is normally difficult to collect using a survey tool, key questions were asked in several different formats: yes/no questions, Likert type scale questions and open-ended questions. Many questions were similar to try to obtain subtle nuances. The questions covered in this section include questions 15, 17, 22-23, 25, 33-34, 38-39.

The first perception question asked was a simple yes/no question inserted at the end of the Usage section. The straightforward question 15 asked, "Do you think LMDSS was user friendly?" Nearly half of the replies were in the "don't know" category (49 percent). Those who gave a yes or no answer were evenly split with forty saying "yes" (26 percent) and thirty-six saying "no" (24 percent). Again the large group of people answering "don't know" may have been due to the extended period of time when the application was not in working order. Overall, these results suggest there is still room for improvement in this area.

Question 17 asked, "If you know of other NALDA applications which contain query formats you would like to see implemented in LMDSS please list them below?" Table 31 summarizes the results of this query.

Category	Number of Respondents	Percentage of Respondents
Not Applicable Don't Know or Left completely blank	130	86 %
Entered comment	**22**	**14 %**

Table 31 Summary of Respondents' Recommendations about Other NALDA Formats

The only general theme appearing among most of these responses was simplicity. Users did not appear to hold strong opinions about query format as long as it was easy to learn and apply. The Aircraft Inventory and Readiness Reporting System (AIRRS) and the Aircraft Engine Management System (AEMS) were the only two NALDA applications that received at least three or more recommendations. One worthwhile comment came from an ILS manager from SPAWAR who suggested, "No NALDA applications come to mind, but you could apply the NSLC (shipboard) equivalent called "3M OARS". That application is very user friendly with ad-hoc reporting, conversion to commercial database software and web access."

Questions 22 and 23 were Likert type questions developed to assess how the users perceived the underlying structure of the software application program. The first

question targeted how much importance the user attached to knowing the structure of the report generation formulas and the second queried the usefulness of having an imbedded data dictionary.

The results of question 22, "How important is it for you to know the details concerning how LMDSS reports are derived before you feel you can trust the information they provide?" are displayed in Table 32 and Figure 16.

Category	Coding	Number of Responses	Percentage of 152 Respondents
Extremely Important	1	48	32 %
Very Important	2	34	22 %
Somewhat Important	3	29	19 %
Not Very Important	4	10	7 %
Not at All Important	5	0	0 %
Don't Know, NA	NA	31	20 %

Table 32 Importance of LMDSS Report Derivations

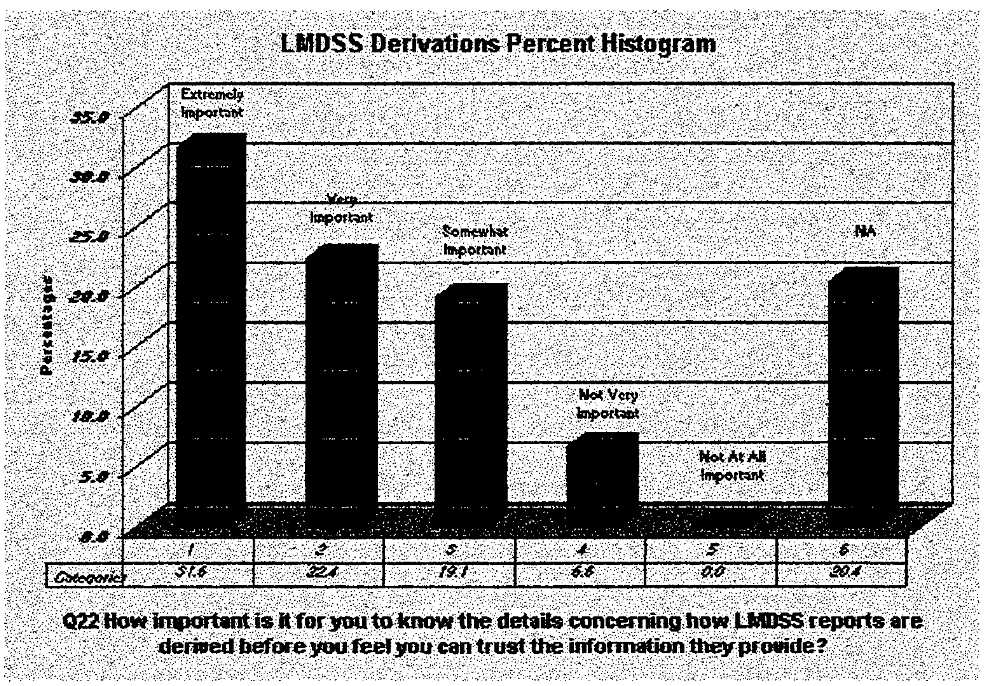


Figure 16 Importance of LMDSS Report Derivations Percent Histogram

Nearly eighty percent of all respondents entered an opinion for question 22 and over fifty percent felt that it was "extremely" or "very important" to understand how data are derived by LMDSS in order to trust the data. This question does not address the reason why users believe this but it would be interesting to investigate the relationship between this question and the users reported inability to access the program reliably.

Category	Coding	Number of Responses	Percentage of 152 Respondents
Extremely Important	1	57	38 %
Very Important	2	49	32 %
Somewhat Important	3	20	13 %
Not Very Important	4	5	3 %
Not at All Important	5	0	0 %
Don't Know, NA	NA	21	14 %

Table 33 Importance of LMDSS Data Dictionary

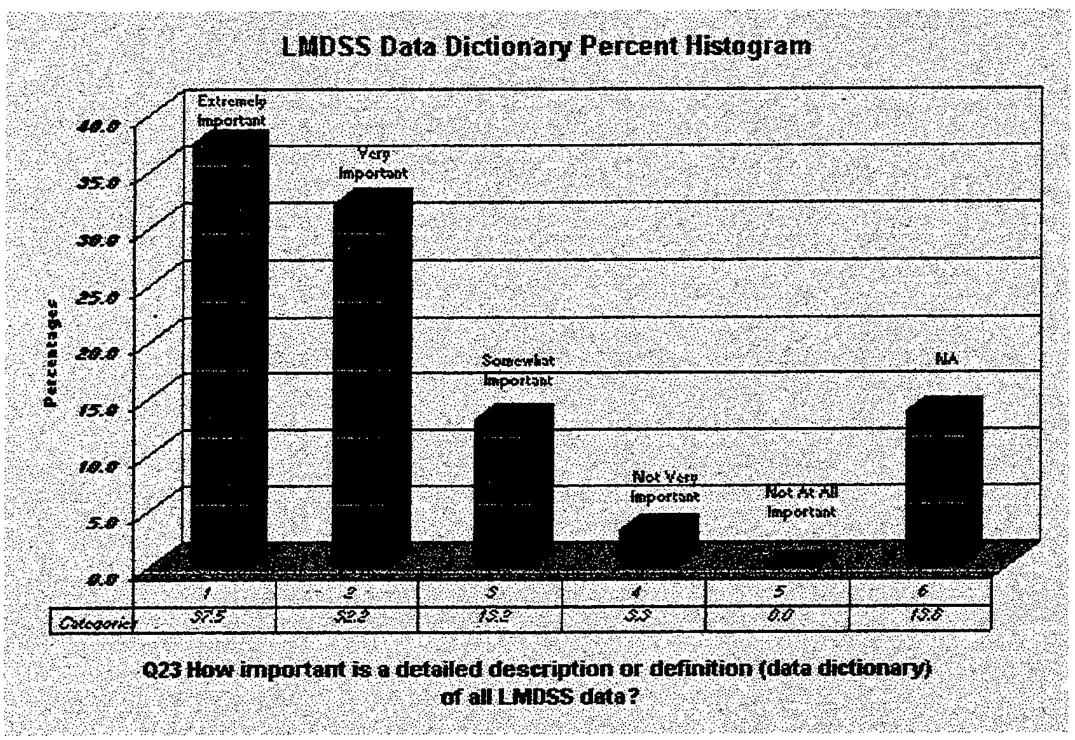


Figure 17 Importance of LMDSS Data Dictionary Percent Histogram

Question 23 queried, "How important is a detailed description or definition (data dictionary) of all LMDSS data?" The results are displayed in Table 33 and Figure 17.

Question 25 was another straightforward question asking, "Have you found the usage of definitions and metrics by LMDSS to be in compliance with established 3M definitions?" Since usage was measured to be low in Figure 4, a large number of meaningful responses was not expected. The results supported this expectation and are displayed in Table 34.

Category	Number of Responses	Percentage of 152 Respondents
Yes	32	21 %
No	5	3 %
Don't Know	113	74 %

Table 34 Compliance with 3M Definitions Summary Results

Question 31 requested users to "Please describe any examples of your not being satisfied with the quality of the data you have obtained through LMDSS." The summary results are provided in Table 35. Many of the comments contained more than one example. Table 36 provides a frequency breakdown of types of user answers.

Category	Number of Responses	Percentage of 152 Responses
Not Applicable	92	60 %
None	24	16%
Don't Know	9	6 %
Did not reply	3	2 %
Entered comment	**24**	**16 %**

Table 35 Summary of Examples of Dissatisfaction with Quality of LMDSS Data

Comment Categories	Number of Responses	Percentage of 152 Responses
LMDSS data not current or accurate	16	11 %
Difficult to filter and obtain desired data	6	4 %
Poor quality of 3M data from organizational level	5	3 %
Unable to access desired modules	4	3 %
No data for desired aircraft type, model, series	4	3 %
LMDSS failure data did not agree with older systems	2	1 %
Cost per flight hour calculations erroneous	2	1 %

Table 36 Summary of Respondents' Comments

Some specific comments received from the responses to this question are listed below:

> Couldn't get the right cut of engine information. It was simply too hard to figure out how to get what I wanted.
> USMC - Maintenance Officer

> When data is normalized by flight hours it often is presented as all zeros...
> Systems Command - Logistics Management Specialist

> ...I was never able to get into many engine analysis areas. Half the area was always under repair.
> Type Command - Logistics Analyst

> Was told (LMDSS) data was inaccurate, so did not use to a great degree...I did compare F404 engine/module removals with AEMS and the numbers were off (engine transaction report data base did not agree with your NALCOMIS 3M data base
> Civilian Firm - Engine analyst

> Depot maintenance data at the present time is inaccurate because of limited data being received from level 1 and 2 in the Depot...
> Depot - Maintenance Coordinator

> On the few occasions I've used LMDSS, the databases and info I needed were not loaded or current.
> Civilian Firm - Systems Analyst

I have no formal training of this system and found it impossible to use. I have visited six AIMDs and only two AZs were competent in drawing down data... CNAP maintains their own data base on site.

Fleet Command - Management Analyst Manager

To be honest, I got frustrated using the LMDSS system. It did not provide the information that I would need at the time so I usually built my own NALDA S2K queries and pull down my data in my that way.

Depot - Analyst

Questions 33 and 34 asked, "Has anyone from NAVAIR or the LMDSS development team ever contacted you requesting your input/feedback concerning LMDSS?" and "Have you ever attended a NAVAIR sponsored LMDSS users' group meeting?" respectively. Twenty eight users (18 percent) responded that they had been contacted for input concerning LMDSS but only five people (three percent) reported attending a LMDSS users' group meeting. Of those who attended, two were from depot, one was from a civilian firm, one was from COMNAVAIRRESFOR and one was from a systems command.

The open-ended question 38 asked, "In what ways could NAVAIR make analysts more aware of LMDSS?" Table 37 summarizes the responses to this question. Fifty users entered comments for this question. Many of the comments contained more than one recommendation. Table 38 provides a frequency breakdown of how many users suggested each strategy NAVAIR could employ to make analysts aware of LMDSS.

Category	Responses	Percentage of 152 Responses
Don't Know	56	37 %
Entered comment	**50**	**33 %**
Not Applicable	42	28 %
Did not reply	4	3 %

Table 37 Summary of Suggestions on How to Increase Awareness of LMDSS

Comment Categories	Responses	Percentage of 152 Responses
Training at field activities and 'A' schools	20	13 %
Email	7	5 %
Web page	6	4 %
Word of mouth	6	4 %
Naval message traffic	5	3 %
Chain of command	3	2 %
Navy publications	3	2 %
NAVAIR newsletter	3	2 %
Periodic LMDSS user conferences	1	1 %

Table 38 Summary of Types of Suggestions on Increasing LMDSS Awareness

Some specific comments received from the responses to this question are listed below:

If you build it they will come!
NAVICP systems analyst

Email notices...maybe like the NAVAIR Team Newsletters or the BPR announcements that periodically show up in our emails.
Systems Command - Operations Research analyst

Most people have been aware of LMDSS or the lack of LMDSS for years. If it's up and running awareness will take care of itself.
Systems Command - NAVAIR Deputy Department Head

Get it up and running...Ensure data correctness. Let people access it and the word will spread if it's good.
Civilian firm - System Analyst

Have a LMDSS user conference yearly. The group meeting could be run similar to the old NALDA user group meetings. Discuss problems, concerns, and recommendations for a better system...
Depot - Analyst

C. ESTABLISHING DIFFERENCE NULL HYPOTHESES

In order to answer the difference, or user group comparison, questions described in the previous chapter, the following null hypotheses were developed:

- H_o: There is no significant difference between the *user category groups* (officer, enlisted, GS, civilian) with respect to the importance they assign to a modeling/simulation capability in future versions of LMDSS.

- H_o: There is no significant difference between the *organization type* groups (Fleet command, System command, Type command, etc.) with respect to the importance they assign to a modeling/simulation capability in future versions of LMDSS.

- H_o: There is no significant difference between the *user category groups* in how important they consider a graphics capability to be in future LMDSS updates.

- H_o: There is no significant difference between users in the various *organization types* concerning how important they view a graphics capability to be in future LMDSS updates.

- H_o: There is no significant difference between *user category groups* with respect to the importance assigned to being able to cleanly export LMDSS data to applications with graphics capabilities such as Excel.

- H_o: There is no significant difference between users within the various *organization types* concerning the importance they assign to being able to cleanly export LMDSS data to applications with graphics capabilities such as Excel.

- H_o: There is no significant difference between *user category groups* concerning the importance assigned to the addition of a structured, ad-hoc query tool to the LMDSS application.

- H_o: There is no significant difference between the *organization types* concerning the importance assigned to the addition of a structured, ad-hoc query tool to the LMDSS application.

- H_o: There is no significant difference between the *user category groups* in how often LMDSS is accessed via the Web.

- H_o: There is no significant difference between the users within the various *organization types* in how often LMDSS is accessed via the Web.

D. ANOVA TESTS

1. Meeting ANOVA Criteria

A one-way ANOVA was used to compare the means of sample/groups in order to test for significant differences. ANOVA assumes the DV is interval scale, normally distributed, and the variances of the groups are equal. If the assumptions are violated, an equivalent nonparametric test called the Kruskal-Wallis (K-W) test can be used to compare the mean ranks of the groups. The IVs in this study are represented as ordinal data while the DVs were measured on an interval scale. The distributions of each of the five DVs measured were compared to a normal distribution curve to ensure they approximated the distribution of a normal curve. The equality of variances was tested using the Levene test. If the Levene statistic was significant (sig < .05), the assumption of equal variances was violated and the K-W test was conducted to compare with the ANOVA results. (Morgan and Griego, 1998)

SPSS software provides a metric called the significance level, or sig, which allows the researcher to easily interpret a calculated statistic in a computer generated output without looking up the critical value in a table. Sig can be considered to be the probability of a Type I error. A Type I error is the likelihood of rejecting the null hypothesis when it is actually true. If the reported sig is less than .05 the finding is statistically significant and the null hypothesis (no difference) is rejected. (Morgan and Griego, 1998)

The ANOVA statistic only compares means between groups and is used to identify a statistically significant difference between means. If the overall F value calculated by an ANOVA test is significant (sig < .05) then there is a statistically significant difference between groups with respect to the DV. Any further information comparing the means to each other is done with post hoc tests. Post hoc tests are only done if the overall F is found to be significant.

2. ANOVA Testing Results

ANOVA testing of each of the ten null hypothesis did not reveal any statistically significant differences among various user categories and organization type groups concerning the measurements of the DVs. In the three instances where the Levene Test revealed the violation of the equal variances ANOVA assumption, the K-W nonparametric test was conducted to see if a different result could be attained. In all three cases the K-W test results agreed with the ANOVA results. None of the null hypotheses could be rejected.

Specific pairs of organization type groups were selected for ANOVA testing to determine if a difference could be detected with respect to measurements of the DVs and none was detected. All thirteen organization types were combined into three groups: (1) higher echelon military commands, (2) lower echelon military commands, and (3) private contractors. Subsequent ANOVA testing did not reveal any evidence supporting the rejection of the null hypotheses of no differences between the groups. Table 39 provides a summary of the results of the one-way ANOVA testing conducted on the ten null hypothesizes. Since none of the ANOVA testing resulted in a significant difference between group means, post hoc tests were not conducted.

E. PHONE INTERVIEW FINDINGS

Seventeen phone interviews were conducted from a randomly selected sample of 25 LMDSS users. The major themes common to the majority of the interviews were:

- Many expressed a strong desire for accurate and timely data.
- Users want to be able to conduct effective ad-hoc queries on their own.
- More training is needed on the use of the ad-hoc IQ tool within LMDSS.
- The capability to drill down to the Maintenance Action Form (MAF) level is considered critical in investigating maintenance and logistics issues.

H_0 (IV and DV)	Calculated F value for ANOVA	ANOVA Sig Value	K-W Sig Value	Can H_0 be Rejected?
User Cat and Modeling	F(3,78) = .068	.977	Levene Test not significant	NO
Org Type and Modeling	F(11,70) = .343	.973	Levene Test not significant	NO
User Cat and Graphics	F(3,120) = 1.15	.334	Levene Test not significant	NO
Org Type and Graphics	F(12.111) = .93	.412	Levene Test not significant	NO
User Cat and Data Export	F(3,148) = .96	.412	Levene Test not significant	NO
Org Type and Data Export	F(12,139) = .92	.529	.496	NO
User Cat and Ad-Hoc Tool	F(3,97) = 1.14	.338	Levene Test not significant	NO
Org Type and Ad-Hoc Tool	F(12,88) = 1.14	.340	Levene Test not significant	NO
User Cat and Freq of Use	F(3,97) = .922	.433	.507	NO
User Cat and Freq of Use	F(12,88) = 1.17	.316	.181	NO

Table 39 ANOVA and Kruskal-Wallis Test Results

- Most users interviewed had little experience or knowledge of models, simulations, and sensitivity analysis and were not interested in them at their level.

- Analysts want to understand how data are derived to include any assumptions, definitions, and algorithms.

- Most users interviewed expressed a lack of confidence in the accuracy and timeliness (two to three months late) of AV-3M data.

- Many users expressed their frustration in knowing very little about the various data analysis software tools developed by NAVAIR.

- Several users recommended teaching students at both the Data Analyst and A schools about LMDSS and other NALDA II applications.

- The majority of users recounted an unsatisfactory experience with LMDSS as a result of difficulties with queries and limited amounts of data.

- Those familiar with the IQ tool found it extremely complex, requiring intensive attention to detail.

- Most of the communication between the LMDSS users interviewed and NAVAIR occurs during sessions between the NAVAIR 3.6.2 help desk personnel.

- None of the users reported being contacted specifically for user feedback concerning LMDSS.

- All users contacted had some form of a Pentium computer on their desk with a way of accessing the Web.

- The majority of logistics analysts interviewed wanted the capability to track the parts much like FEDEX and UPS tracks shipments in the commercial world. Currently, finding the status of an ordered part, its location, and who controls its distribution takes a day's worth of phone calls to NAVICP. Several users on WING and TYCOM staffs considered this an important capability.

Some statements recorded from those interviewed were as follows:

> Using LMDSS needs to be as easy as following the bouncing ball!
>
> Email is the best way for NAVAIR to stay in touch with customers at all levels. Email is a religion here.
>
> I'd like one big database in the sky which lets me choose the data elements I need.
>
> LMDSS is not very user friendly. I got lost trying to do queries. It needs to be more user friendly like Optimize NALCOMIS.
>
> I accessed LMDSS almost daily in the Fall of '98 for data queries. I was not aware the data within LMDSS was corrupted and the database had been frozen!
>
> I've served 15 years in the Navy at the organizational level and I never heard of NALDA until I got to the TYCOM staff.

LMDSS has not progressed enough to allow me to write my own queries like I did under NALDA I. LMDSS doesn't have the depth of the canned reports I accessed under NALDA I.

We developed our own program called 'Forecast' which uses NAVFLIRS and comptroller info to conduct cost analysis, cost comparison, and degrader identification. Forecast can supply data within 10 days instead of the three months it takes LMDSS.

I have been an active proponent of the technology change offered by LMDSS since its idea and conception years ago, but there is not any usable information there for me to provide my customers so I am not a user.

F. INTERVIEWS WITH PAST AND PRESENT LMDSS MANAGERS

During the period of this research, most of the managers within NAVAIR 3.6.2 were interviewed both in person and over the phone. Some individuals no longer assigned to NAVAIR 3.6.2 were also located and interviewed by email and phone calls. The major findings of these interviews are summarized below:

- No evidence could be found suggesting the use of automated software tools for documentation, test cases, defect tracking, and configuration management.

- Little documentation exists which accurately describes the eight year history of the LMDSS project in a manner capable of supporting meaningful "lessons learned" training. There is a lack of historical software measurement data.

- A formal risk management program documenting threats and strategies to minimize them has never been conducted.

- LMDSS has undergone several major requirements changes as well as at least four program manager changes.

- Milestones and deadlines have been established and reestablished several times during the history of the LMDSS program.

- The use of 8A contractors with limited technical capabilities and a poor understanding of LMDSS requirements resulted in years of delays and rework.

- The LMDSS project is often funded out of hide and has never had its own line of funding. LMDSS has suffered more than one 50 percent budget cut during its development.

- Estimates of the time required, man-hours, and size of LMDSS related work was determined by dividing available funding by the cost of available, qualified programmers.

- Changes in programming languages required extensive rework of the canned reports.

- Most LMDSS requirements are developed by maintenance and logistics experts on the NAVAIR staff. A robust strategy of involving LMDSS users from the Fleet to provide feedback and input has not been implemented.

VI. DISCUSSION AND ANALYSIS

A. WHERE IS LMDSS NOW?

In December 1998, LMDSS was taken offline to correct data error problems and load a minimum of eighteen months of AV-3M data for all types of Navy aircraft. The goal was to get LMDSS back online within a few months and complete QA testing by the scheduled NALDA I termination deadline of March 1999. This deadline was primarily motivated by a DISA mandate that all systems be Y2K compliant or terminated by March 1999. Continuing high data error rates and problems loading the AV-3M data resulted in further delays in completing the LMDSS QA testing. Finally, NAVAIR 3.6.2 directed LMDSS be brought back online beginning May 1999 while QA testing continued. Although LMDSS is now back online and considered operational, only four aircraft platforms (E-2, H-60, S-3, A-6) are loaded as of August 1999.

Currently, NAVAIR is continuing to struggle with loading the data into the underlying database structure. Data loads must be completed before all interface connections can be properly reviewed for integrity. Parallel operations with both NALDA I and II servers are scheduled to continue during the months of September and October, 1999. In addition, there are three major short-term goals still unaccomplished by LMDSS developers:

- Load at least eighteen months of data for all type equipment codes.
- Successfully implement the automated update process using AV-3M data from the Streamline Alternative Logistics Transmission System (SALTS).
- Reduce the high data error rate within the databases that feed LMDSS.
-

Until these objectives are accomplished, the usefulness of LMDSS as an effective management information system will be severely limited.

B. RESEARCH QUESTIONS

This section applies the findings of our research in answering the research questions introduced in earlier chapters.

1. What can future software developers learn from studying the LMDSS project?

A well-documented history of the eight-year LMDSS project is important because it will provide invaluable lessons for future NAVAIR development teams. Many of the classic mistakes described in the Literature Review and Appendices of this thesis were identified during interviews with selected LMDSS program managers. The actual LMDSS software programmers currently contracted by NAVAIR were not interviewed during this research. Additional interviews with these programmers, their predecessors, and a few of the previous program managers not contacted will be required in order to capture a more complete LMDSS development history.

The most significant factors that contributed to delays in the LMDSS development effort included the following:

- Absence of a formal risk management program
- Major requirements changes
- Lack of funding support
- Proper contracting support
- New technology
- Lack of user input
- Personnel turnover

A more detailed summary of additional software development mistakes that occurred during the LMDSS project is documented in section F of the Findings chapter.

a) Formal Risk Management

A formal risk management program specifically addressing the LMDSS application was never implemented by NAVAIR during the history of the LMDSS project. The literature review described formal risk management as a proven, fundamental software development practice. The early identification of risks, evaluation of risks, and subsequent implementation of strategies to minimize the impact upon software development project is critical in the avoidance of major obstacles.

b) Major Requirements Changes

Transitioning LMDSS from a UNIX to a Web environment resulted in significant LMDSS requirement changes. A formal risk management program might have fostered additional communication and planning which would have allowed developers to be better prepared for the impact of these changes.

The majority of the major requirement changes experienced by the LMDSS program were responses to the exponential rate of improvements in networking, computers, and Internet technology within the last few years. Additional changes to the LMDSS project included the abandonment of the Ada and ActiveX codes for the newer Oracle and Java languages. Future development teams should study how these changes were implemented to learn the importance of proactive planning and estimating using formal risk management and software metrics.

c) Funding Support

LMDSS has suffered several major budget cuts during its history. Interviews with two previous LMDSS program managers revealed estimates of the time required, man-hours, and size of LMDSS related work were largely based on available funding instead of requirements. No evidence could be found suggesting that automated software tools, Computer Aided Software Engineering (CASE) tools, or standard software metrics were used to develop accurate estimates in planning and scheduling LMDSS work. As deadlines passed without LMDSS developers meeting stated goals,

credibility was lost with upper NAVAIR management. This loss of credibility negatively impacted the funding support received by the LMDSS program.

d) Proper Contracting Support

Interviews revealed Small Business Administration (SBA) 8A contractors were used to satisfy key requirements during the transition of LMDSS to the Web environment. On several occasions, the primary 8A contractor failed to deliver the desired software products citing misunderstandings involving LMDSS requirements. More detailed requirements were drafted by the LMDSS program manager and accepted by the contractor. Subsequent attempts by the contractor to meet these detailed requirements were not successful. The primary LMDSS 8A contractor eventually was forced to go out of business and was replaced by a more qualified contractor.

e) New Technology

The new, complex technologies involved in building a Web interface to a massive, integrated database structure has overwhelmed previous LMDSS development teams. Additional funding to support developer training is one solution to dealing with rapidly changing technology. A second solution is to outsource using skilled contractors with a proven track record of successfully completing such large-scale database projects. Either alternative will require additional funding commitments by NAVAIR.

f) Lack of User Input

The literature review showed how the lack of user input and feedback is a common problem among failed software development projects. Strategies implementing user focus groups, user meetings, and periodic e-mail newsletters are all effective means of correcting this problem. Getting back in touch with users should begin with an aggressive attempt to update the entire LMDSS user database maintained by NAVAIR. Multiple attempts by researchers to reach a random sample of LMDSS users by phone and/or e-mail resulted in successfully contacting 74 percent of the sample. The vast

majority of the sampled users had changed e-mail addresses since registering with NAVAIR. Correcting the e-mail addresses of the remaining LMDSS users will require a dedicated effort but will be worth the effort if a LMDSS e-mail newsletter is ever implemented.

g) Personnel Turnover

LMDSS has had more than its share of personnel turnovers with respect to both program managers and programmers over its eight-year history. Interview findings identified funding cuts as a major cause of the downsizing and personnel turnovers suffered by the LMDSS program. Three NAVAIR managers interviewed stated these turnovers had a negative effect on the LMDSS project. These frequent turnovers also made it difficult to document a detailed history of the LMDSS project.

2. Does LMDSS meet user requirements?

During the majority of this research period, LMDSS was involved in a major overhaul. The survey responses and interviews confirmed that before LMDSS was taken offline in December 1998, it did not provide timely, accurate data to its users.

Developers have considered LMDSS to be in an evolutionary, prototype stage for several years with since its transition to the Web in 1994. LMDSS users were not clearly informed of its prototype status and were not notified of the data error/corruption problems. Moore and Snyder (1998) also identified this lack of communication between NAVAIR and LMDSS users during their research.

The limited LMDSS data loads (which included only a few of the Navy's many aircraft type, models, and series) combined with frequent errors within the data itself both confused and frustrated users. The majority of the random sample of queried LMDSS users abandoned the application after a few failed attempts to acquire useful data. Despite this, user interviews revealed a common eagerness to know the status of

LMDSS, if it was finally working, and, if so, whom they needed to contact to get access again.

Until LMDSS can provide access to timely, accurate AV-3M data relating to the Navy's entire aircraft inventory, LMDSS will continue to be of little value to its users. In addition to the conversion of all AV-3M data onto the new Y2K compliant server, developers are currently struggling to implement a data warehouse structure where all aviation maintenance and logistics databases are integrated, compatible, and easily accessible through LMDSS and other NALDA II applications.

3. What are the significant decisions users would like LMDSS to support?

The vast majority of current LMDSS users are data analysts assigned to the various organizations listed in table 7. Survey responses and interviews revealed LMDSS is used more as a database interface and report generator than as a decision support tool. Questions in the Web survey designed to capture the significant decisions LMDSS needs to support were difficult for users to answer. Frequently, users answered with requests for specific types of data instead of addressing the types of decisions such data need to support. This was particularly apparent in the survey findings from questions 18 and 37.

Interviews revealed major decisions supported by LMDSS users involve:

- Life-cycle costs
- Reliability centered maintenance decisions
- Historical performance of aircraft systems, parts and engines
- The impact of program decisions on readiness
- Comparing the performance of maintenance activities at all levels
- Forecasts of the future reliability of aircraft systems

PMAs and APMLs, who for the most part are not direct users of LMDSS, need to be queried more thoroughly to gain sorely needed insight into what specific decisions need to be supported on a continual basis.

4. What are the key attitudes and opinions of the LMDSS users?

The statistical ANOVA testing conducted on the four group comparison questions described in methodology, did not result in a statistically significant difference among the various user groups with respect to:

- User requirements
- Modeling and simulation
- Graphics
- Exporting LMDSS data
- Ad-hoc query tool
- How often LMDSS is accessed

Some of the key attitudes expressed by LMDSS users during this research were:

- Users placed a strong emphasis on receiving accurate and timely data.
- Users have been frustrated with the limited data and quality of data available through LMDSS. Users have abandoned LMDSS until it delivers the data they need.
- Users want to be able to conduct their own ad-hoc queries within LMDSS. Most feel that additional IQ training is required.
- Users want to be able to export data downloaded from LMDSS into a familiar user tool like Excel so that they can do graphical presentations. An internal graphical capability would be welcomed but the primary concerns were exportation of data and ease of use.

- Based upon their past experiences, users do not trust LMDSS as a reliable source of data and therefore want to know how data is derived and defined.

- Users overwhelmingly agreed that e-mail is the best way for NAVAIR to stay in touch with its customers at all levels.

5. How has LMDSS been funded?

In the past, LMDSS has received its funds from the NALDA program funding and has never been assigned its own line of funding. LMDSS managers identified severe cuts in funding and personnel as the major causes for many of the delays and problems suffered during the eight-year LMDSS development effort. Recently, much of the funding for LMDSS development efforts has come "out of hide" from NAVAIR's Operation and Maintenance funds.

As NALDA I is closed down in October 1999, LMDSS will take on a far greater importance as the primary gateway to all of the Navy's AV-3M historical data. An aggressive POM effort needs to be, initiated to acquire the funding necessary to finish existing plans for LMDSS and to ensure proper funding for maintenance and future development

6. How can LMDSS be improved to better meet managerial needs?

a) Provide accurate and timely data.

A common perception held by LMDSS users is that most AV-3M data errors occur at the hangar deck level because maintenance technicians do not have an appreciation of how important it is to provide correct maintenance and logistics data. An effort to work with the Chief of Naval Education and Training (CNET) to include more detailed NALDA/LMDSS training in the appropriate A schools and technical training centers would go far to help correct this data entry problem. A CD-ROM multimedia tutorial mailed to all Fleet aviation commands might be one way to alleviate this problem. Such a tutorial could show maintenance and logistics technicians how

important AV-3M data is to making correct strategic program decisions at the PMA level.

An aggressive effort by NAVAIR is needed to hold wings and squadrons accountable for the quality of AV-3M data submitted. Linking this effort to periodic command inspections would do much to motivate squadrons to pay closer attention to the quality of their submitted data.

b) Make LMDSS more user friendly.

Although a monumental effort has been made to make LMDSS easier to use, only twenty-six percent of the users who responded to the Web survey considered LMDSS to be user-friendly. The poor quality of LMDSS data and the significant effort involved in accessing needed data surely contributed to this attitude.

An idea promoted by the current NAVAIR 3.6.2 would be to customize LMDSS for each individual user in a manner similar to the Yahoo and CNN Web sites. Upon first registering at the LMDSS site, a user could customize the site to provide only specifically required data and reports. This personalized site environment would appear every time the user subsequently logged-on to LMDSS. All desired data and reports would be updated and available every time the user visited his uniquely designed LMDSS site. Automated tools could be used to inform the user when requested metrics of interest had changed. Current Web technology that pushes data to personalized Web sites could be implemented to continually update a user's individualized "My LMDSS Home Page" with the most current data available. Personalized icons could be created by the user on this home page to quickly bring up commonly needed reports containing the most recent data.

A file folder tab format as found on many of today's popular Web sites might help LMDSS users find their way to desired data easier than requiring them to drill down into imbedded modules. Interviews revealed users want more extensive help screens and help functions. Users place a higher importance on just getting accurate,

timely data than details concerning report formats. As one analyst stated, "Using LMDSS needs to be as easy as following the bouncing ball."

c) *Enable users to easily export LMDSS data to an application supporting graphics and spreadsheets like MS Excel.*

LMDSS users strongly expressed their need to cleanly export data to applications with graphics capabilities like Excel. The survey questions relating to this topic received the most responses in both quantity and in the strength of the users' conviction. (See results of questions 24 and 32 in the Results section of Findings.) Although internal graphical capabilities were also desired, the users were clear that they needed to be able to cleanly export data to complete further analysis on the material provided by LMDSS. Users interviewed seemed willing to make compromises on specific data format as long as the data was accurate, timely, and could be downloaded to an application and manipulated by the user.

d) *Revise the IQ tool to be more user friendly or abandon the current IQ tool and develop a new, easier to use, ad-hoc query tool within LMDSS.*

LMDSS users place a high importance on their ability to develop individualized ad-hoc queries. Users familiar with the IQ query tool within LMDSS reported it as too difficult to use. Only two percent of LMDSS users surveyed found the IQ tool to be user friendly. Users expressed their frustration upon completing IQ tool training when they discovered they were unable to overcome LMDSS access and software difficulties. Others reported losing most of the IQ skills acquired during training when they were unable to practice using the tool because of various problems accessing LMDSS data.

A search engine similar to those found in other Web sites (altavista.com, dogpile.com, yahoo.com, amazon.com) is one suggestion for making ad-hoc queries easier to implement. Data contained in common report templates could be developed with the help of extensive user interviews. These reports could be easily accessed by an

Internet style search engine interface familiar to most Web surfers. Such a search engine would make it easier for users to conduct a customized search. The search engine would hide the complicated details of SQL coding from the user just as Web site authoring tools now hide the complex details of HTML code.

e) *Provide a modeling/simulation capability.*

If LMDSS is ever upgraded to become a fully functioning decision support tool, as its name implies, it will have to eventually include extensive modeling and simulation capabilities. As shown in the literature review, modeling and simulations are an essential part of a DSS. Previous LMDSS research by Moore and Snyder (1998) determined modeling is needed by both PMAs and APMLs to better forecast life-cycle costs and predict the effect of program decisions on those costs and overall readiness.

The active involvement of PMA/APMLs will be required to develop the models and simulations needed to meet their unique decision support needs. DSS modeling requirements will have to be thoroughly documented and financially supported in the Program Objectives Memorandum process by NAVAIR senior leadership to be successfully implemented.

Some of the modeling applications LMDSS users suggested included models that would:

- Assist in predicting future maintenance support requirements
- Estimate life cycle costs and the impacts of aging
- Capture various return on investments for proposed readiness and program changes
- Forecast spare costs and failure trends

A prototype model built by the authors of this thesis provides an example of how modeling and simulation could assist logistics and maintenance managers. The model, designed to help wing maintenance managers forecast the readiness impact of a real-

world depot support problem, is presented in Appendix F. The model enables users to conduct sensitivity and "what if" analysis to assist in making strategic, unstructured decisions.

7. How can NAVAIR improve the LMDSS program?

NAVAIR has several major difficulties facing them as they struggle to make LMDSS an effective analysis tool for the Fleet. These include:

- Ensuring the final LMDSS product performs properly within established quality specifications.
- Ensuring LMDSS meets user requirements.
- Convincing users LMDSS is capable of providing accurate, meaningful data.
- Training new and repeat users how best to use LMDSS.
- Continuing to develop new and/or better capabilities into the system.

Although the findings of this research discovered numerous areas that could be improved upon, the following are the significant areas of concern identified by the research:

a) Improve communications with users

Managers interviewed within the LMDSS development team believed the experts on the QA team and others at NAVAIR knew what the LMDSS users wanted without asking the users themselves. NALDA user meetings were abandoned as NALDA II and LMDSS underwent development with the intention of reinstating them in the summer of 1998. Months turned into years without a NALDA or LMDSS user meeting. Over eighty percent of the users participating in the Web survey reported they had not been contacted for input by the LMDSS development team. Only three percent reported attending NAVAIR sponsored LMDSS user group meetings. Given the project's history of missing deadlines and not meeting advertised expectations, a dedicated effort needs to

be made to improve communications between the NAVAIR developers and the Fleet customers. This includes identifying a timely means to provide information to the users on the status of LMDSS and a means of obtaining feedback from the users. Elimination of miscommunication will go a long way toward reestablishing a favorable reputation of LMDSS within the user ranks.

Teleconferencing, focus groups, and regional user meetings are alternative means to continuing the critical effort of staying in touch with LMDSS customers in a fiscally constrained environment. Accurate user feedback and input is critical to maintaining meaningful LMDSS software requirements. Assuming those on the LMDSS development team already know what LMDSS users want and need is a risky assumption.

Survey respondents suggested NAVAIR stay in touch with users through the use of an email LMDSS newsletter. Since 99 percent of the users within the LMDSS random sample contacted during this research have email accounts one can assume the majority of the total LMDSS user population also have email accounts. Only two users contacted were aware of the data problems within LMDSS that resulted in data being corrupted and frozen for several months in the fall of 1998. During this period, users were still going to the LMDSS Web site for periodic data searches. A NAVAIR sponsored LMDSS e-mail newsletter would help avoid such misunderstandings, maintain the trust and cooperation of users, and assist greatly in collecting user feedback.

b) Improve LMDSS training.

User comments emphasized the importance of hands-on training with students being assigned to their own computer terminal and practicing with a more realistic sample database. Users expressed their frustration of completing LMDSS training only to discover LMDSS was still under development, delivered inaccurate data, and did not work as promised.

To avoid these misunderstandings, further training should be delayed until LMDSS is fully operational. The abundance of non-response answers to survey questions

and the interview results reveal users have abandoned LMDSS and will continue to do so until it is fixed. Continuing to conduct training before LMDSS can deliver as promised will only worsen NAVAIR's relationship with its customers.

CNET's Electronic Schoolhouse Network (CESN) should be explored to expand the scope of LMDSS training via distance learning. CNET has built several electronic classrooms that are available to support LMDSS training. All of the CESN sites are located at the major Fleet concentration areas. In 1997, a CNET pilot project was conducted to test the viability of completing hands on software training via distance leaning. Software training originating at the Naval Reserve Professional Development Center in New Orleans was transmitted to remotely located electronic classrooms operated by CESN. Software interface difficulties limited the success of this pilot project, but CNET has continued to work toward improving the viability of distance learning and is working on attaining the capability for CESN to conduct remote software training. Utilizing CESN sites would also allow NAVAIR to conduct timely, periodic LMDSS focus groups and user feedback meetings while avoiding cost prohibitive travel expenses.

VII. CONCLUSIONS/RECOMMENDATIONS

A. THE NEED FOR A STRATEGIC DECISION SUPPORT SYSTEM

1. Conclusion: LMDSS does not meet the original requirements established for a strategic decision support system for PMAs/APMLs.

The original requirement for LMDSS was established by NAVAIR 04 and the former Aviation Supply Office (currently renamed NAVICP) in June 1991. This requirement directed the development of a strategic decision support system to assist PMA, APML, and WSM teams in measurably reducing program life cycle costs while minimizing negative effects on Fleet readiness. Many specific DSS capabilities were initially promised to the NAVAIR chain of command in 1993. It was believed the developed program LMDSS would:

- Provide a single source of real-time maintenance and logistics data by accessing as many as nine stovepipe databases
- Allow sensitivity or "what if" analysis based on the ability to manipulate supply and maintenance parameters
- Support detailed causative research
- Provide an audit trail of a manager's decision process
- Forecast engine problems and repair alternatives using the corporate expert knowledge of top engine analysts
- Assess the repair productivity and efficiency of maintenance activities across all organizational levels
- Deliver presentation quality graphic (Naval Air Systems Command, LMDSS Requirements Document, 1993)

The current operational version of LMDSS has none of these capabilities. During its eight-year development, LMDSS has evolved from a DSS design for PMs and APMLs into a limited management information system (MIS) used by data analysts at all levels.

Recommendation: Rename LMDSS and call it a management information system. Validate the requirement for a strategic decision support system to help PMAs, APMLs, and WSMs better manage their programs.

LMDSS users contacted during this research expressed their loss of faith in LMDSS' capabilities as the primary reason for abandoning it. Moore and Snyder (1998) concluded LMDSS did not meet the criteria for a DSS. Consideration should be given to changing the name of LMDSS to more accurately reflect its role as a Web interface that provides AV-3M data for Fleet and civilian data analysts. The capability of LMDSS to drill down into AV-3M data, identify primary cost drivers, present standardized reports, and support ad-hoc queries places it in the management information system category. When LMDSS becomes fully operational a new name might help restore user faith and avoid misunderstandings. A more accurate name for LMDSS would be the Logistics Management Information System (LMIS).

The original requirement for a strategic decision support system to improve program management needs to be further explored and validated again. If this requirement is determined to still be valid, we recommend a strategic decision support system containing models and simulations and supported by an integrated data warehouse be built for NAVAIR program managers. Such a system could provide invaluable assistance to PMAs, APMLs, and WSMs in their daily struggle with unstructured decisions to overcome limited funding and maintain readiness.

2. Conclusion: The key to providing accurate, timely logistics and management data lies in the development of a data warehouse.

An effective strategic decision support system for NAVAIR managers will require the integration of data currently found in stovepipe, legacy and relational databases within NALDA I. A three-tier, data warehouse architecture, containing a meta-data capability, with a middleware based, application interface holds the best promise for achieving this integration.

Recommendation: Develop a data warehouse to support LMDSS.

Developing a data warehouse that seamlessly integrates numerous NAVAIR legacy databases to provide easy access to timely, accurate data is a major undertaking for any organization. A detailed, thorough effort to benchmark other organizations that have successfully completed such a project should yield invaluable "lessons-learned."

To build a data warehouse, transformation and extraction tools will be needed to access the various data types. Meta-data managers will be needed to describe and track the origins of data, how it was cleaned and distributed, who is responsible for it, and how frequently it is updated. In addition, business intelligence tools and data cleansing tools will also be required. (Malloy, 1997)

B. SOFTWARE DEVELOPMENT ISSUES

1. Conclusion: The absence of a formal risk management program is a major contributor to the failure of the eight-year LMDSS program.

A properly implemented, formal risk management program is a proven software development tool for identifying, evaluating and mitigating potential risks. The literature review chapter describes research showing the impact an effective risk management program can have on the success of a software development effort. Although interviews led us to believe formal risk management practices are used in other areas of the NALDA program, the LMDSS project does not appear to have a risk management policy in effect.

Recommendation: Institute a formal LMDSS risk management program

Formal policies requiring periodic reviews of existing and emerging risks present a proven method for software managers to manage the potential risks to a software development project. Risk management will allow the LMDSS development team to anticipate obstacles and proactively develop strategies to mitigate them.

Although a variety of formal methods exist, developing and tracking an up to date list of "Top Ten Risks" to the LMDSS program is a recommended, proven strategy of communicating potential obstacles to both managers and developers (McConnell, 1996).

As risks are controlled and minimized they can be removed from the list and replaced by higher priority risks.

2. Conclusion: Documentation in all areas of the LMDSS program needs to be improved.

As stated in the discussion section, no evidence could be found suggesting the LMDSS project used automated software tools, CASE tools or standardized software metrics to develop accurate estimates for planning and workload scheduling. Without accurate, credible estimates of man-hours required, anticipated lines of code and other proven software development metrics, schedules and deadlines became best guesses. The inability to meet poorly estimated deadlines put additional unneeded pressure on LMDSS team members. Poor documentation also made it difficult for LMDSS program managers to fight for limited funds. As a result, the available funding drove LMDSS requirements instead of the requirements driving the level of funding. This resulted in a "death spiral" causing further delays and decreased capabilities.

Recommendation: Improve the documentation maintained by the LMDSS software development team.

In the same way that trend analysis and configuration management are instrumental in improving aviation maintenance practices, documentation is just as important to software development. Metrics need to be identified and tracked in order to measure progress (or lack of progress) in the LMDSS program. Proper metrics are imperative in order to implement any quality assurance programs. Quality cannot be improved is there are not any standardized methods with which to identify performance or process problems. Risk management documentation and meticulous, thorough schedules based on accurate estimates from software metrics can be influential tools in future attempts to attain additional LMDSS funding support from upper management.

CASE tools should be reviewed for applicability and implemented where appropriate. A dedicated effort needs to be made to document program metrics such as man-hours expended, Lines of Code (LOC) completed, and software errors per LOC (bug density). Contractors should also be providing similar metric data on their development

process for analysis. This data should provide managers with a better means on how best to allocate funding and manpower resources to meet cost and time constraints. Data sampling is another method for verifying accuracy. In addition, accurate documentation is crucial to conducting thorough post-mortem (or lessons learned) summaries to prevent repetition of process problems in future software projects.

3. Conclusion: Major LMDSS requirement changes significantly contributed to its delayed deployment.

LMDSS managers continue to propose major requirement changes prior to successfully completing the current phase of development. As shown consistently in the software development literature, the delays and costs associated with changing core requirements late in the developmental cycle is exponentially proportional to the length of time in the cycle. More simply stated, the earlier a change is implemented, the less impact it will have on schedule and cost. When changes are made in the middle or late in a SW development project, it does not matter whether the reason is due to changes in funding, technology and personnel. The result will be the same: drastic schedule delays and/or exorbitant cost increases. LMDSS suffered every possible requirement change including hardware requirements, software language, contractor changes, personnel changes and user requirement changes. Given this, it is no wonder that LMDSS is over budget, behind schedule and not fully functional.

Recommendation: Identify and validate detailed requirements for LMDSS and implement a versioning strategy to manage future requirements changes.

LMDSS has gone through so many metamorphic changes users do not have a clear understanding of its current capabilities. Program managers need to get back in touch with LMDSS users and thoroughly document their requirements. When LMDSS is fully deployed, NAVAIR needs to properly advertise its strengths and limitations to its customers. As shown in the findings, the majority of users did not know specifically what LMDSS could do.

Implementing a versioning technique, similar to Microsoft's tactic of developing its MS Office line, would enable continued developmental improvements while still focusing programmers on meeting core program requirements. LMDSS needs to adopt a policy that mirrors Microsoft's Office marketing practices. Program managers need to identify a core set of capabilities that LMDSS should have and strive to complete production. Major changes resulting from new technologies, new personnel or funding constraints should be reviewed for potential integration into LMDSS. If evaluations of new requirements are favorable, a plan should be developed to implement the new requirements into a future version of the application instead of trying to continually change the existing development process.

4. Conclusion: Lack of continued user involvement in the LMDSS development project contributed to its failure to meet customer needs.

As covered extensively in the Findings chapter and again in the Discussion and Analysis chapter, communications between users and developers is poor. Over eighty percent of the users participating in the Web survey reported they had not been contacted for input by the LMDSS development team and only three percent reported attending NAVAIR sponsored LMDSS user group meetings. Due to the years of conflicting reports about the capabilities of the LMDSS application, most users do not have a clear understanding of what exactly the LMDSS program can do. As evidenced in the survey results, many users are willing to provide input but have not been asked.

Recommendation: NAVAIR needs to improve communications with LMDSS users.

Findings showed users prefer a NAVAIR sponsored LMDSS e-mail newsletter but teleconferencing, focus groups and regional user meetings are alternative means of improving user feedback and ensuring two way communications.

In order for LMDSS to better meet user requirements, NAVAIR managers need to actively involve users in the development process. Periodic LMDSS user meetings, focus groups, and aggressive e-mail correspondence are recommended strategies for NAVAIR to employ to get back in touch with its LMDSS customers.

5. Conclusion: Until LMDSS can provide access to all AV-3M data for every platform in the Navy's current inventory, LMDSS will continue to not meet user needs.

As stated before, without AV-3M data properly loaded for all type/model/series and type equipment codes, LMDSS will continue to provide only limited usefulness. Interviews with NAVAIR managers revealed LMDSS developers failed to appreciate the complexity of building an integrated database support structure. Y2K compliance measures, inadequate contracting and data security concerns further complicated the transition of data into the system. This has resulted in repeated difficulties loading the data.

Recommendation: Complete the loading of AV-3M data for all type/model/ series aircraft to enable access by LMDSS users.

All data needs to be loaded as soon as possible so that all users may obtain the data required. Future LMDSS development efforts need to be supported by adequate funding, skilled data warehouse experts, and a major contractor with a track record of implementing similar data warehouse projects.

C. AREAS FOR FURTHER RESEARCH

The following areas for future LMDSS research are:

- Conduct a follow-on survey of LMDSS users once LMDSS is fully functioning with access to all historical aircraft and logistic data.
- Explore the NALDA II data warehouse plan and research alternative strategies to support LMDSS integration.
- Conduct an in-depth analysis into the causes of LMDSS data errors and recommend ways to improve the quality of LMDSS data reports.
- Validate and define the need for a strategic DSS by NAVAIR program managers.
- Develop models to assist NAVAIR program managers in making strategic, unstructured decisions with the goal of improving readiness while cutting program costs.

APPENDIX A. CLASSIC SOFTWARE DEVELOPMENT MISTAKES

McConnell (1996) identified and described thirty-six classic mistakes that directly lead to a failed software development effort. His list is divided into the four categories of people, process, product, and technology.

1. People

- Undermined motivation
- Weak personnel
- Uncontrolled problem employees
- Heroics
- Adding people to a late project
- Noisy, crowded offices
- Friction between developers and customers
- Unrealistic expectations
- Lack of effective project sponsorship
- Lack of stakeholder buy-in
- Lack of user input
- Politics placed over substance
- Wishful thinking

2. Process

- Overly optimistic schedules

- Insufficient risk management
- Contractor failure
- Insufficient planning
- Abandonment of planning under pressure
- Wasted time during the fuzzy front end
- Cuts to requirements analysis, architecture, and design
- Inadequate design
- Shortchanged quality assurance
- Insufficient management controls
- Premature or overly frequent convergence
- Omitting necessary tasks from estimates
- Planning to catch up later
- Code-like-hell programming

3. Product

- Requirements gold-platting (more requirements than needed)
- Feature creep (changing requirements)
- Developer gold-platting
- Approval of a schedule slip while adding additional requirements
- Research-oriented development

4. Technology

- Silver-bullet syndrome (a single new practice will solve schedule problems)

- Overestimated savings from new tools or methods
- Switching tools in the middle of a project
- Lack of automated source-code control

APPENDIX B. NALDA II

The Naval Aviation Logistics Data and Analysis (NALDA) system is an automated, relational database and information retrieval system for aviation logistics management and technical decision support. NALDA Phase I first became operational in the early 1980s and evolved from the need to improve the data analysis capabilities of logistics and aviation program managers as Navy's aviation weapons and support systems became more complex and sophisticated. In the mid 1990s, NALDA Phase II expanded the data base and analysis capability to include all Fleet logistics elements. (SPAWAR, 1999)

The primary objectives of the NALDA Phase II system is to leverage information technology to achieve process improvements through the following:

- More timely and accurate information and tools
- Affordable readiness and total ownership cost metrics and process tools for decision makers
- Easier information access to managers, logisticians, engineers and maintenance technicians at all levels within the Fleet
- Create and store data once, and use it many times
- Integrate with the Department of Defense's Standard and open systems architecture, minimizing stovepipes, redundancies, and islands of automation. (NAVAIR, 1999)

All NALDA II applications, one of which is LMDSS, will be structured within a single shared, logical, and physically distributed Integrated Weapons Systems Data Base (IWSDB). The IWSDB will be a centralized Oracle object-oriented data base structure that will contain all relevant naval aviation logistic data. (Joseph Interview, 1998)

APPENDIX C. FOCUS GROUP QUESTIONS

Initial questions:

- Who are the Users? List Categories/Activities
- What are the levels of users?
- Demographics? Provide information about the users. See below.
- What are the users doing with LMDSS now from your perspective?
- What are the most common help requests?
- What do the users want to do with it now?
- What is the future of LMDSSS going to look like?
- What do you like/dislike about the old survey?

Additional questions that arose during the focus group

- Do TYCOMS hire people that may also have/need access?
- Do contractors have restricted access?
- What information do you want to receive from the survey?
- What about the change from Unix to the Web?
- Do you think the lost graphical capabilities will be a problem?

Demographics recommended by focus group:

- Command/Activity
- Type Users
    - Active Duty
    - Contractor
    - Civilian
    - GS Worker
- Job Title
- IT Experience
- Rate/Rank
- Internet access
    - Frequency
    - Type connection - modem/network connection
- Type organizational category
    - AIMD
    - APML
    - Staff
    - Depot

APPENDIX D. WEB-BASED SURVEY

Logistics Management Decision Support System (LMDSS) Survey

Thank you for your assistance in this LMDSS research effort sponsored by NAVAIR 3.6.2. This survey was prepared by CDR Mark Krause (mwkrause@mbay.net) and LCDR Ellen Evanoff (evanoffrus@aol.com) from the Naval Postgraduate School. The purpose of our research is to assist NAVAIR with the identification of LMDSS user requirements in order to develop a better decision-making tool for the Logistics and Maintenance communities. The quality of the data from this survey will depend solely on the honesty and accuracy of your input.

In Feb 99, LMDSS was removed from the Web and is currently being reworked and updated. Despite the fact LMDSS will not be available for use for several months, we are very much interested in your past experience with LMDSS and what you would like it to do for you in the future.

The identity of those responding to this survey will be kept strictly confidential. Some basic information is requested in case we need to contact you at a later date. If there are any questions, both CDR Krause and LCDR Evanoff can be reached via their email addresses listed above. So, lets get started!

Q.Name
What is your name?

____
____
____

Q. Email
What is an email address we may use to contact you?

____
____

Q.Command
Please provide your command name (or name of business) and job title.

____
____

1. How often did you access LMDSS when it was available on the Web?
   - ❍ Infrequently
   - ❍ Monthly
   - ❍ Weekly
   - ❍ Daily
   - ❍ Don't know
   - ❍ Not applicable

2. Choose the term below which best describes your organization:
   - ❍ Fleet Command (CINCLANT,CINCPAC,COMTHIRDFLT,..)
   - ❍ Type Command (COMNAVAIRPAC,COMNAVAIRLANT,..)
   - ❍ Systems Command (COMNAVAIRSYSCOM,SPAWAR,...)
   - ❍ COMNAVRESFOR
   - ❍ COMNAVAIRESFOR
   - ❍ Naval Safety Center
   - ❍ Marine Corps Activity
   - ❍ Navy Inventory Control Point
   - ❍ Depot
   - ❍ AIMD
   - ❍ WING
   - ❍ Squadron
   - ❍ Civilian Firm under contract to the Navy
   - ❍ Other

3. How long has it been since you last accessed LMDSS?
   - ❍ Less than 6 months
   - ❍ 6 -12 months
   - ❍ 1 - 2 years
   - ❍ 2 - 3 years
   - ❍ 3 - 4 years
   - ❍ 4 - 5 years
   - ❍ More than 5 years
   - ❍ Don't remember
   - ❍ Not applicable

4. When were you first introduced to LMDSS?
   - ❍ Fewer than 6 months ago
   - ❍ 6 -12 months ago
   - ❍ 1 - 2 years ago
   - ❍ 2 - 3 years ago
   - ❍ 3 - 4 years ago
   - ❍ 4 - 5 years ago
   - ❍ More than 5 years ago

❍ Don't remember
❍ Not applicable

5. When the LMDSS Web site comes back online, what will be your primary means of accessing it?
❍ 28K modem
❍ 56K modem
❍ ISDN connection
❍ T-1 connection
❍ Via the network
❍ Don't know
❍ Other

6. What kind of problems did you have accessing LMDSS? (Check all that apply)
❑ I have not had any problems.
❑ Firewall blocking access
❑ Proxy difficulties
❑ Downloading matrix tables
❑ Unable to access the IQ tool
❑ Computer hardware inadequate
❑ Internet browser issues
❑ Other
❑ Don't know, just couldn't access the LMDSS web site

7. When LMDSS is back online, users will be required to use Netscape Communicator 4.5 with 128 bit encryption (available for free download at www.netscape.com). Do you anticipate any problems downloading and installing this browser?
❍ Yes
❍ No
❍ Don't know
❍ Not applicable

8. What kind of software problems did you experience while using LMDSS? (Write NA or "No problems", if appropriate)

____
____
____

9. What kind of information do you expect to retrieve from LMDSS when it becomes available? (Write "Don't Know" or NA, if appropriate)

____
____

10. What information do you require, but are unable to access via LMDSS? (Write "Don't Know" or NA, if appropriate)

____

____

11. How difficult was it to build matrix tables within LMDSS?
- ❍ 1 Impossible
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5 Easy
- ❍ Not applicable

12. Which LMDSS modules did you access the most (check all that apply)?
- ❑ Management Analysis
- ❑ Candidate Identification
- ❑ Trend Analysis
- ❑ Cost Analysis
- ❑ Detailed Analysis
- ❑ Supply Analysis
- ❑ Engine Analysis
- ❑ Reference Information
- ❑ Application Management Tools
- ❑ Change Requests
- ❑ Feature Synopsis
- ❑ Other
- ❑ Don't know
- ❑ Not applicable

13. Have you ever used the IQ tool to build any custom queries?
- ❍ Yes
- ❍ No
- ❍ Don't know
- ❍ Not applicable

14. Do you think the IQ tool was user friendly?
- ❍ Yes
- ❍ No
- ❍ Don't know
- ❍ Not applicable

15. Do you think LMDSS was user friendly?

- ❍ Yes
- ❍ No
- ❍ Don't know

16. How important do you consider the addition of a structured, ad-hoc query tool to LMDSS?
    - ❍ Extremely important
    - ❍ Very important
    - ❍ Somewhat important
    - ❍ Not very important
    - ❍ Not at all important
    - ❍ Don't know
    - ❍ Not applicable

17. If you know of other NALDA applications which contain query formats you would like to see implemented in LMDSS please list them below? (Write "Don't know" or NA, if appropriate)

____

____

18. Please list a few of the key decisions you would like LMDSS to support when it comes back online. (Write "Don't Know" or NA, if appropriate)

____

____

____

19. LMDSS will collect much of its raw data from NALCOMIS. If there is any data you will require which is not captured by NALCOMIS, please describe it below? (Write "Don't know" or NA, if appropriate)

____

____

____

20. How important do you consider the development of a modeling/simulation capability in future versions of LMDSS?
    - ❍ Extremely important
    - ❍ Very important
    - ❍ Somewhat important
    - ❍ Not very important
    - ❍ Not at all important
    - ❍ Don't know
    - ❍ Not applicable

21. Can you provide an example of how a modeling/simulation capability to conduct sensitivity (what if) analysis will be useful? (Write "NO" or NA, if appropriate)

____

____

____

22. How important is it for you to know the details concerning how LMDSS reports are derived before you feel you can trust the information they provide?

- ❍ Extremely important
- ❍ Very important
- ❍ Somewhat important
- ❍ Not very important
- ❍ Not at all important
- ❍ Don't know
- ❍ Not applicable

23. How important is a detailed description or definition (data dictionary) of all LMDSS data?

- ❍ Extremely important
- ❍ Very important
- ❍ Somewhat important
- ❍ Not very important
- ❍ Not at all important
- ❍ Don't know
- ❍ Not applicable

24. How important do you consider the development of a graphics capability in future versions of LMDSS?

- ❍ Extremely important
- ❍ Very important
- ❍ Somewhat important
- ❍ Not very important
- ❍ Not at all important
- ❍ Don't know
- ❍ Not applicable

25. Have you found the usage of definitions and metrics by LMDSS to be in compliance with established 3M definitions?

- ❍ Yes
- ❍ No
- ❍ Don't know

26. How would you rate the quality of the LMDSS instruction you have received from NAVAIR personnel?

- ❍ Did not receive any training
- ❍ Excellent
- ❍ Good
- ❍ Fair
- ❍ Poor
- ❍ Don't remember
- ❍ Not applicable

27. Did the training include Structured Query Language training using the IQ tool?

- ❍ Yes
- ❍ No
- ❍ Don't remember
- ❍ Not applicable

28. Do you feel you will need LMDSS refresher training when LMDSS comes back online?

- ❍ Yes
- ❍ No
- ❍ Don't know

29. How important is "hands on" LMDSS training with each student assigned to a computer terminal?

- ❍ Extremely important
- ❍ Very important
- ❍ Somewhat important
- ❍ Not very important
- ❍ Not at all important
- ❍ Don't know
- ❍ Not applicable

30. How can LMDSS training be improved? (Write "Don't Know" or NA, if appropriate)

____

____

____

31. Please describe any examples of your not being satisfied with the quality of the data you have obtained through LMDSS? (Write "None" or NA if appropriate)

____

____

32. How important is it for future versions of LMDSS to be able to cleanly export data to applications with graphics capabilities such as Excel?

- ❍ Extremely important
- ❍ Very important
- ❍ Somewhat important
- ❍ Not very important
- ❍ Not at all important
- ❍ Don't know
- ❍ Not applicable

33. Has anyone from NAVAIR or the LMDSS development team ever contacted you requesting your input/feedback concerning LMDSS?

- ❍ Yes
- ❍ No
- ❍ Don't know

34. Have you ever attended a NAVAIR sponsored LMDSS users' group meeting?

- ❍ Yes
- ❍ No
- ❍ Don't remember
- ❍ Not Applicable

35. What might some of your reasons be for using LMDSS when it returns to the Web? (Check all that apply)

- ❑ Find data to support logistics acquisition decisions
- ❑ Reduce life cycle support costs of aviation systems
- ❑ Conduct trend analysis
- ❑ Search for data to complete periodic reports and forms
- ❑ Identify high cost drivers to conduct cost analysis
- ❑ Track the results of implemented improvements
- ❑ Measure the impact of decisions or policies on platform readiness
- ❑ Measure the effect of improvement actions on support costs
- ❑ Identify system degraders
- ❑ View cost data and flight hour history of aircraft engines
- ❑ Drill down to the MAF level to determine cause of system degraders
- ❑ Compare the performance of my command with similar commands
- ❑ Reliability information
- ❑ Other (Please describe in question # 43)

36. If you selected "other" in the previous question, please describe below:

____

37. Referring to your answers in question # 35 and # 36, what do you anticipate your primary reason for using LMDSS will be?

38. In what ways could NAVAIR make analysts more aware of LMDSS? (Write "Don't Know" or NA if appropriate)

39. If you have any additional thoughts as to how NAVAIR could improve LMDSS please write them below: (Write "Don't Know" or NA if appropriate)

APPENDIX E. PHONE INTERVIEW QUESTIONS

1. What activity/command do you work for?

What is your job title? Describe your background with IT systems. How many years of experience do you have with the 3M system? In what capacities have you worked with the 3M system?

2. Are you an active LMDSS user?

No: Why don't you use LMDSS? Why do you still have an active LMDSS account? What would you want LMDSS to do to motivate you to use it regularly?

Yes: How often do you use LMDSS?

3. How do you access LMDSS?

How do you connect to the Internet? (network, modem, ISDN, T-1) Any problems connecting to LMDSS via the WWW? What kind of computer do you use to access LMDSS? (CPU type/speed, RAM, hard drive) Any problems with firewalls? Any software problems related to LMDSS? What kind of browser do you use? Any problems downloading matrices?

4. Have you received LMDSS training from NAVAIR?

When was the training? Where did you receive the training? Did the instructors effectively teach the material? Did the training include SQL training? How can LMDSS training be improved? Do you feel you need refresher training. Did the training adequately prepare you to effectively use LMDSS? Why or why not?

5. Have you used the Help Desk?

No: Why not?

Yes: What is your opinion of the performance of the Help Desk? How often do you call the Help Desk? Any problems reaching the Help Desk? Are the Help Desk personnel able to adequately answer your questions? What are your most common Help Desk requests?

6. How useful is LMDSS?

What questions are you usually trying to answer with LMDSS? Do you consider LMDSS to be user friendly? What information does LMDSS not provide? Any problems building the matrices? Which matrices do you access the most? Is the information easy to get from LMDSS or are there too many steps? Does the flow of data seem logical and easy to follow?

7. Have you used the IQ tool to build any SQL queries?

Do you feel comfortable using the IQ tool to build SQL queries? Is the IQ tool user friendly? Should a more structured, ad-hoc query tool be developed that's easier to use? Do any other NALDA applications contain query formats you would like to see used in LMDSS?

8. What are the key decisions you would like LMDSS to support?

Does LMDSS provide the information you need to make these decisions? What data do you need which is not captured by NALCOMIS?

9. How would a modeling capability be helpful in supporting your research?

Describe modeling as models or simulations, which allow the user to test "what if" scenarios. Discuss whether sensitivity analysis (changing variables to see how the outcome is affected) is an important capability for LMDSS users. Probe for specific examples or stories that show how useful modeling might be for LMDSS users.

10. How would a graphics capability be useful?

Probe for specific examples or stories. Would the capability to export to an application with a graphics capability such as Microsoft's Excel be useful?

11. What is the best way NAVAIR could make analysts more aware of LMDSS?

How did you become aware of the LMDSS and its capabilities?

12. How would you improve LMDSS to make it better?

Probe for examples.

APPENDIX F. SH-60B LOGISTICS MODEL

As shown in the review of the literature, models provide a DSS with powerful analytical capabilities. Sensitivity analysis using models and simulations allows managers to change problem variables to measure their impact on the final outcome of a proposed alternative solution. Although LMDSS does not contain models or simulations, this appendix provides an example of how modeling can assist managers in the evaluation of alternatives to a real world, unstructured problem.

The SH-60B LAMPS MKIII helicopter community has been struggling to overcome a readiness degrader involving a shortage of Ready for Installation (RFI) main rotor blade spindles. The primary cause of the shortage is the backlog of spindles awaiting maintenance at the H-60 Depot in Corpus Christi, Texas. The Depot is tasked to repair H-60 spindles submitted for overhaul by both the Army and Navy. Due to shortages in manpower, training, and funding the Depot has been unable to keep up with the demand for RFI spindles. As a result, Navy SH-60B helicopters often remain in a None Mission Capable (NMC) status for one to three months awaiting a RFI spindle from the supply system.

The purpose of this model is to provide NAVAIR 3.6.2 with a prototype tool capable of sensitivity analysis and "what if" projections. The global time variable for the model is in hours. The time frame for each model run is 88,400 hours or approximately 10 calendar years. Figures 18 and 19 are the two output graphs provided at the end of each model run. Figure 18 shows the result of a 120 hour (5 day) delay at the Depot given the assumption there are 336 "flying" spindles assigned to 84 helicopters in the Pacific Fleet (PACFLT) and 20 spare spindles in the supply system. In Figure 18 the top blue area of the graph shows only 304 RFI spindles in PACFLT after 10 years with the black line showing 52 of the total 356 spindles are in the Depot awaiting maintenance. The red line depicting the number of spindles in the supply system is hidden within the horizontal

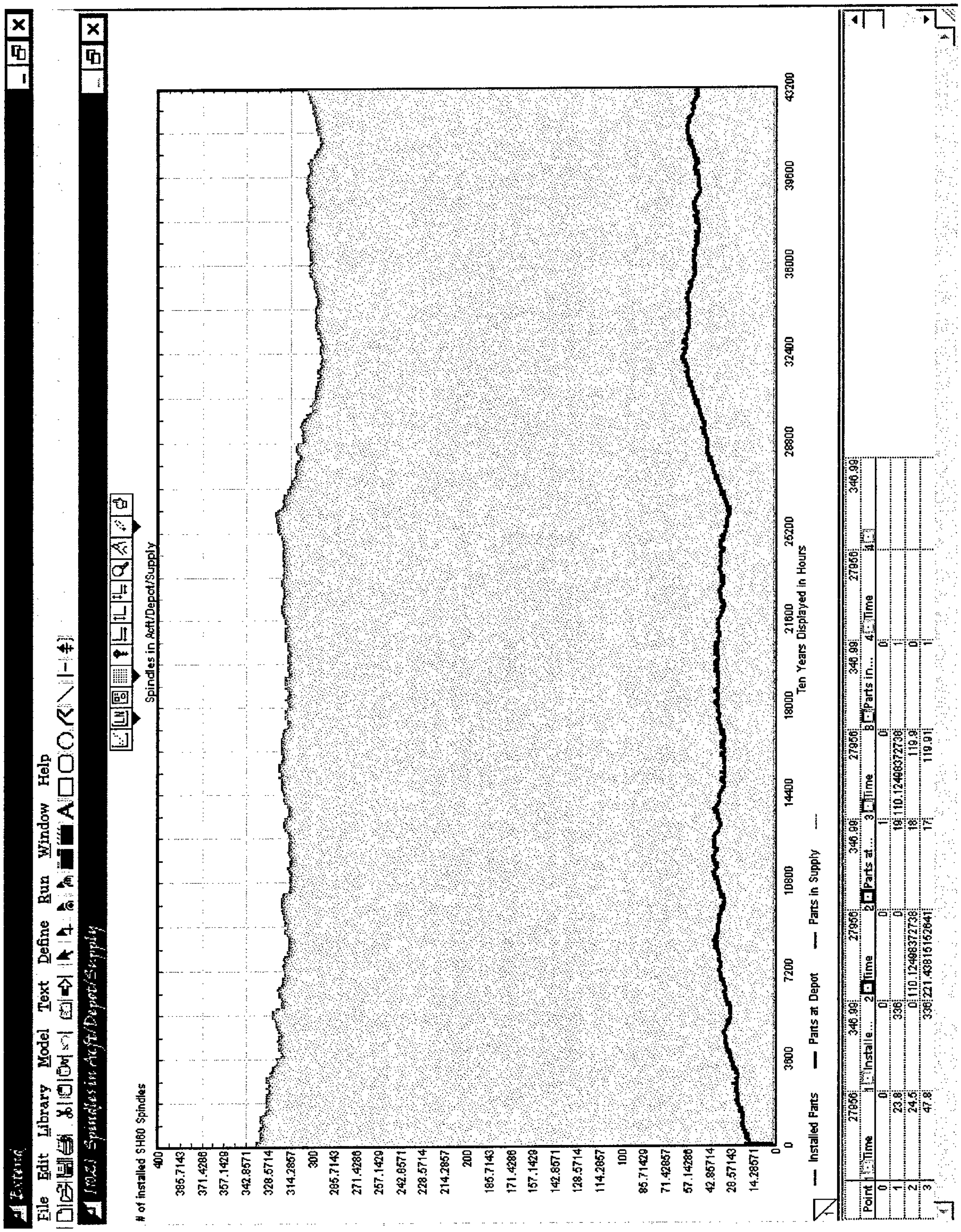


Figure 18 Model Output Showing Status of Spindles

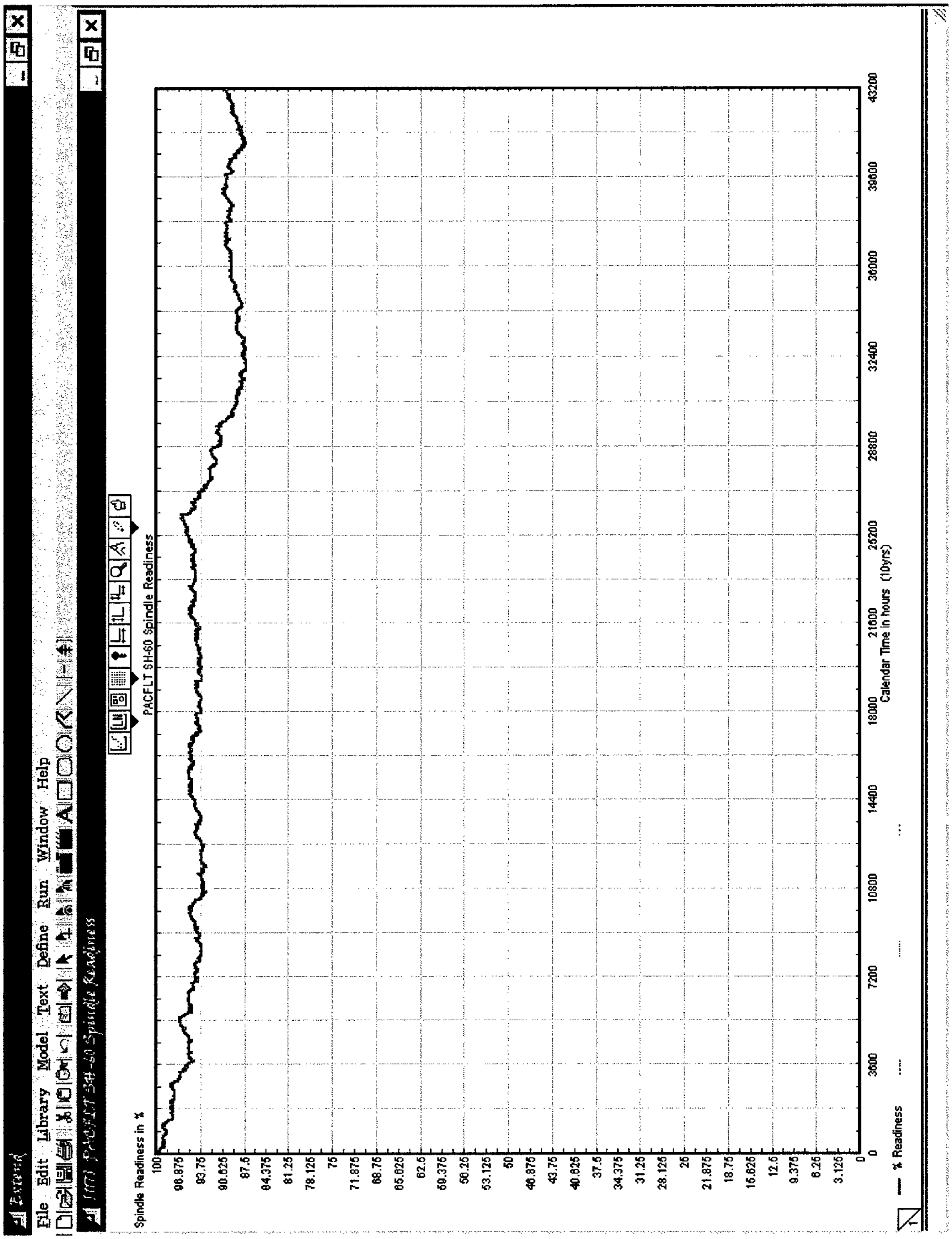


Figure 19 SH-60B Spindle Readiness Plot

graph axis showing a steady value of zero since the Depot never catches up enough to provide any spare spindles to the supply system.

Figure 19 shows the impact on the readiness of PACFLT's SH-60Bs due solely to a nonavailability of main rotor spindles. The plot shows the readiness shortfall (from a maximum of 100 percent) caused by the H-60 Depot's delay in providing RFI spindles to PACFLT's 84 SH-60Bs flying approximately 100 hours a month. Over a ten year period, the Depot delay eventually causes a readiness degradation of approximately ten percent.

Figures 20 through 22 show the actual model in an object-oriented format. Extend modeling software was used to create the SH-60B Logistics Model. The model is divided into various sections simulating helicopters (each containing 4 spindles) flying 3.3 hours each day at the squadron, spindles being checked and removed at 5000 flight hours, spindles being repaired at the Depot, and RFI spindles being passed to supply for transfer back to the Fleet. Attributes such as flight hours remaining to overhaul and daily flight hours are assigned to each spindle as it passes through the system. Attribute generators are assigned constant values or probability distributions with means and standard deviations to approximate model variables. The Depot delay, for example, is initiated from a random input generator assigned a normal distribution with a mean of 120 hours (five days) and a standard deviation of twelve hours.

The power of this model is that variables such as the length of the Depot delay, helicopter flight hours flown per month, the time period of the model, and the number of surplus spindles in the supply system can all be changed prior to each run to see the impact on the final spindle readiness of PACFLT's helicopters. With a few clicks of a mouse on selected objects shown in Figures 20 through 22, any single or multiple variable change can be accomplished. The output graphs provide a clear visual display of the results of those changes to help strategic managers determine where to best apply funding to achieve desired results.

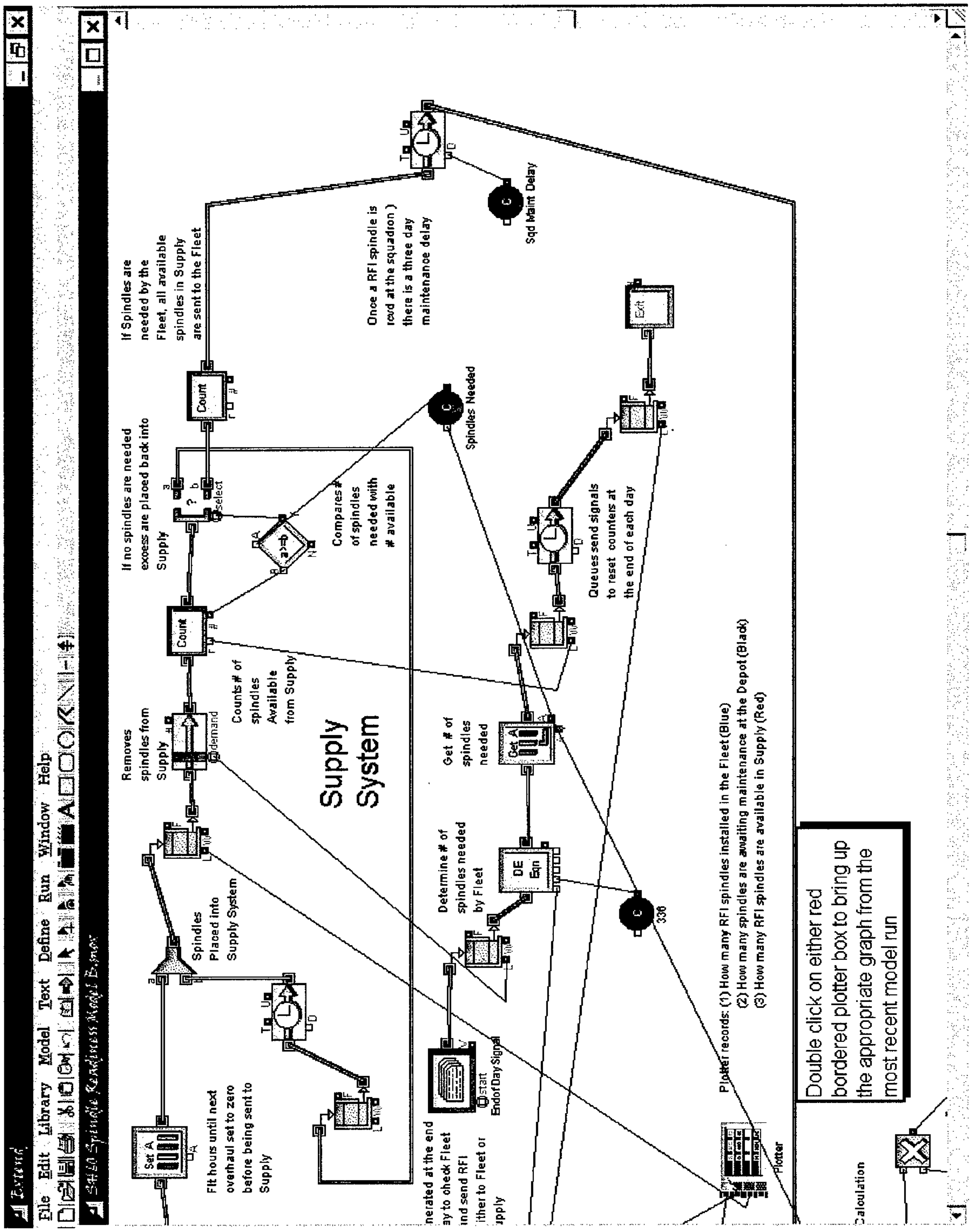


Figure 20 Supply Section of the SH-60B Model

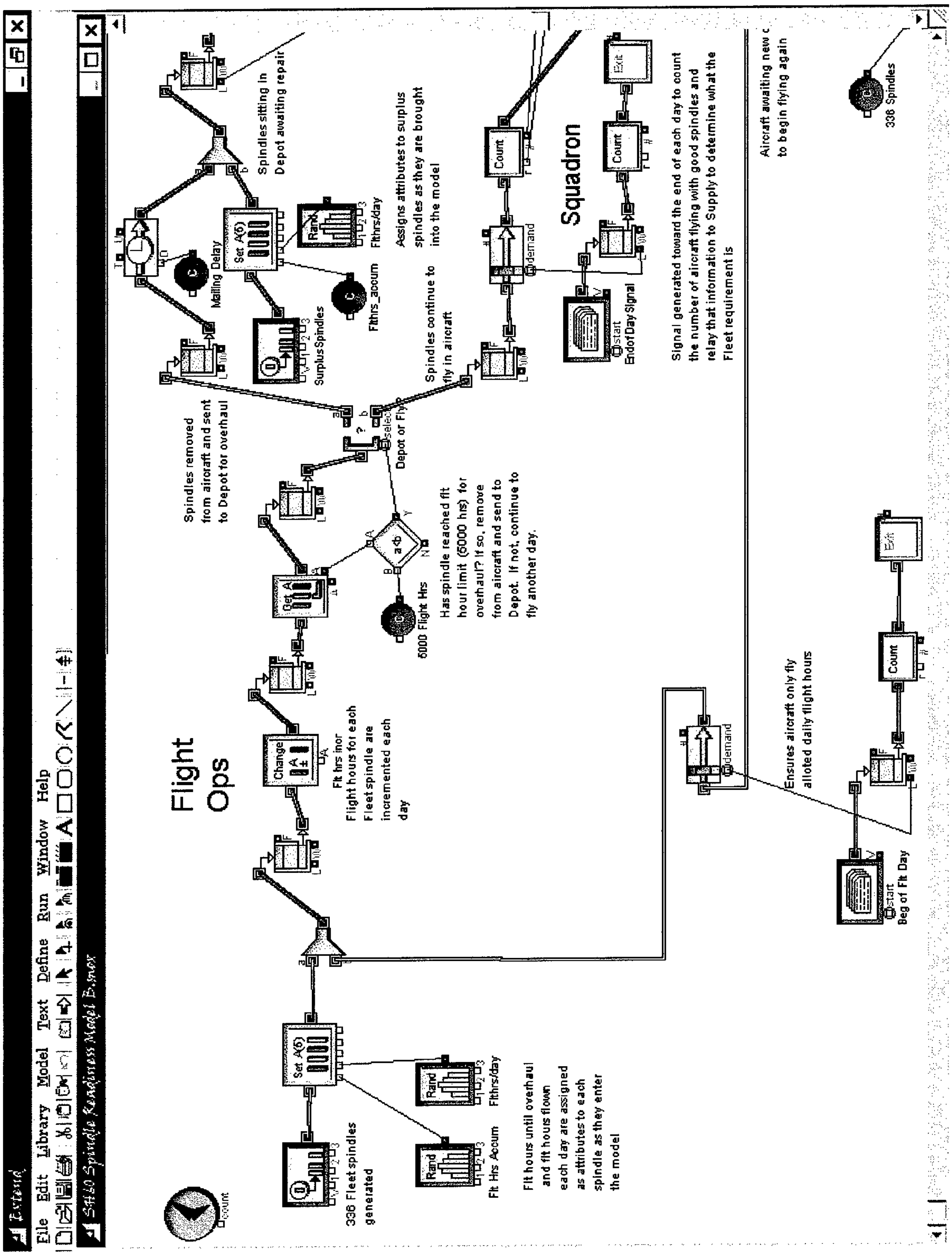


Figure 21 Flight Operations and Squadron Sections of the SH-60B Model

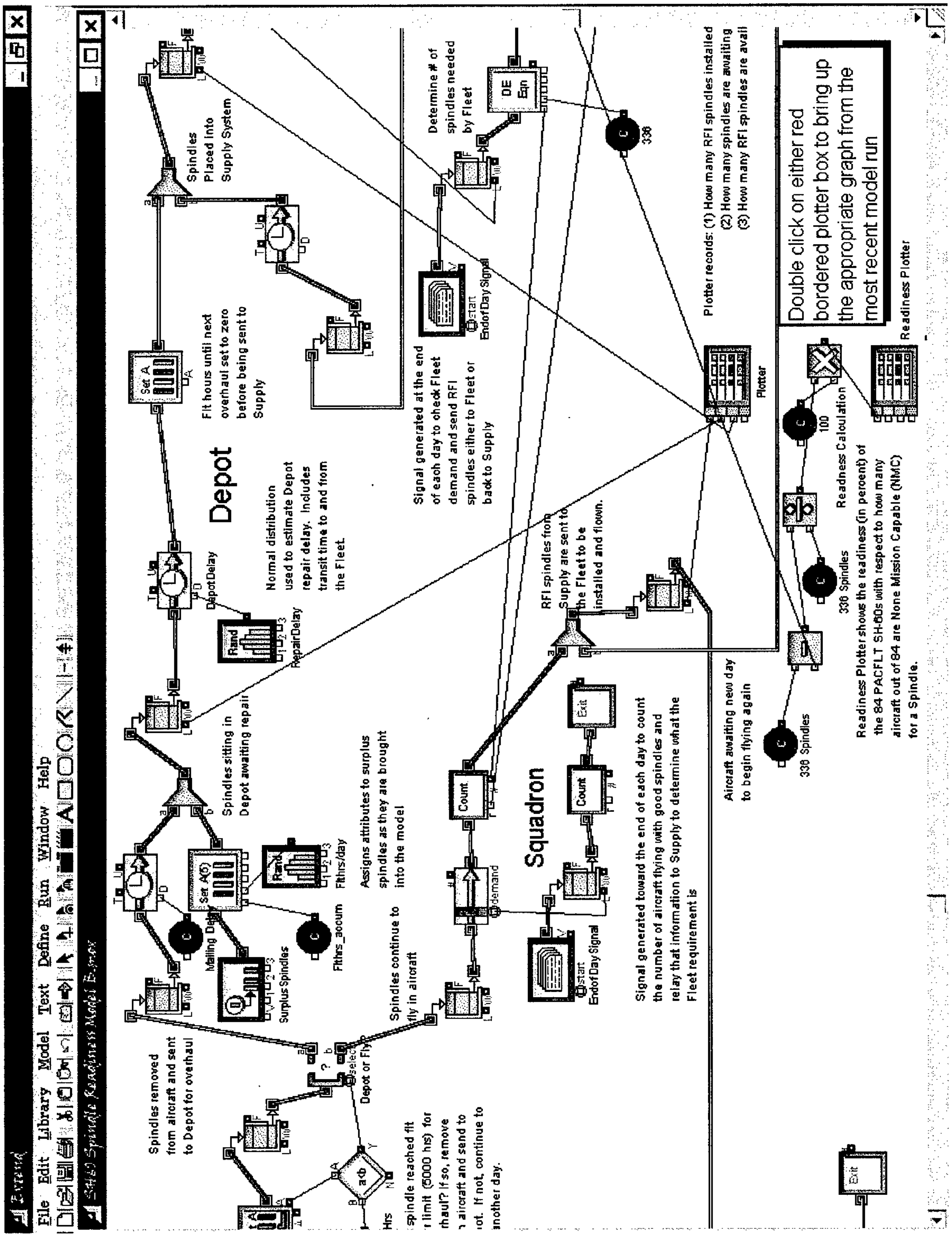


Figure 22 Depot and Squadron Sections of the SH-60B Model

The data for the SH-60B Logistics Model were provided by the COMNAVAIRPAC's LAMPS MK III Wing. The following assumptions are simulated within this model:

- The LAMPS MKIII Wing "owns" 84 SH-60B helicopters. This model only considers these 84 aircraft and does not take into account additional helicopters owned by the Naval Reserve, Army, and the Atlantic Fleet.
- A main rotor spindle must be removed for maintenance every 5000 flight hours and sent to the Depot for overhaul.
- Each SH-60B flies an average of 100 flight hours a month and has four spindles, one for each rotor blade.
- A spindle has never failed in flight. Spindles are only removed at the mandatory 5000 flight hour maintenance interval. Cannibalizations or swapping spindles between aircraft to optimize readiness was not simulated. A helicopter is "down" or non-flyable without a RFI spindle installed.
- The average turn-around time for a spindle includes three days transit time from squadron to Depot, five days repair time at the Depot, three days transit time back to the squadron, and three days to reinstall the spindle.
- It was assumed there are approximately 20 surplus spindles in the supply system.
- There are usually zero available RFI spindles in the supply system each month.
- Once a RFI spindle is received by the squadron, it takes 3 days to install the spindle and complete the post-maintenance check flight.
- To date, a spindle has never been received as non-RFI from the H-60 Depot.

LIST OF REFERENCES

Alter, S., *Information Systems: A Management Perspective*, Addison-Wesley, 1992.

Alter, S., *Decision Support Systems*, Addison-Wesley, 1980.

Ariav, G. and Ginzberg, M. J., "DSS Design: A Systematic View of Decision Support," *Communications of the ACM*, vol. 28, no. 10, pp. 1045-1052, 1985.

Bhargava, H. K. and Krishnan, R., "On Integrating Collaboration and Decision Analysis Techniques," *Journal of Organization Computing*, vol.4, no. 3, pp. 1-23, 1994.

Boehm, B.W. and Papaccio, P. N., "Understanding and Controlling Software Costs," *IEEE Transactions on Software Engineering*, vol.14, no. 10, pp. 1462-1477, 1988.

Cambell, D. T., and Stanley, J. C., *Experimental and Quasi-Experimental Designs for Research,* Rand McNally, 1963.

Card, D. N., "A Software Technology Evaluation Program." *Information and Software Technology,* vol. 29, no. 6, pp. 291-300, 1987.

Cooper, D. R., and Emory, C. W., *Business Research Methods*, Irwin/McGraw-Hill, 1995.

Hetzel, B., *Making Software Measurement Work: Building an Effective Measurement Program*, John Wiley & Sons, 1993.

Jahn, D., NAVAIR 3.6.2, Telephone interview with Ellen Evanoff, 5 March 1999.

Jones, C., *Assessment and Control of Software Risks,* Yourdon Press, 1994.

Jones, C., "Our Worst Current Development Practices," *IEEE Software,* March, vol. 13, No. 2, pp. 102-104, 1996.

Jones, C., "Patterns of Large Software Systems: Failure and Success." *IEEE Software*, March, pp. 86-87, 1995.

Joseph, J., NAVAIR 3.6.2, Interview with the authors, 6 Nov 1998.

Kitson, D. H. and Masters, S. M., "An Analysis of SEI Software Process Assessment Results: 1987-1991," *Proceedings of the 15th International Conference on Software Engineering,* May, pp. 68-77, 1993.

Krantz, L., *The National Business Employment Weekly Jobs Rated Almanac*, John Wiley & Sons, 1995.

Little, John D.C., "Models and Managers: The Concept of a Decision Calculus," *Management Science*, vol. 16, no. 8, pp. B446-B485, 1970.

Malloy, A., "Data Mart Dynamics Tutorial," *Computerworld,* vol. 31, no. 38, pp.99-102, 1997.

MATCOM 2 Memorandum, "Draft Benefits Analysis (BA) for the Logistics Management Decision Support System (LMDSS)," 14 January 1994.

McConnell, S., *Rapid Development*, Microsoft Press, 1996.

Moore, Ellen and Snyder, Carolynn, "Logistics Management Decision Support System: An Effective Tool to Reduce Life Cycle Support Cost of Aviation Systems?," Master's Thesis, Naval Postgraduate School, Monterey, CA, June 1998.

Morgan, G.A., and Griego, O. V., *Easy Use and Interpretation of SPSS for Windows: Answering Research Questions with Statistics,* Lawrence Erlbaum Associates, 1998.

NAVAIR 3.6 Powerpoint Brief, "Aviation Maintenance/Logistics Information Systems: Information Brief for AMSR Study Group 3," 13 January 1999.

NAVAIR 3.6.2, Homepage, http://nalda.navy.mil/3.6.2, May 1999.

Naval Air Systems Command, "Acquisition Program Baseline, Naval Aviation Logistics Data Analysis Program," 9 September 1997.

Naval Air Systems Command, http://aso2.nalda.navy.mil . May 1999.

Naval Air Systems Command, "Logistics Management Decision Support System Requirements Document," Draft of 15 December 1993.

Naval Air Systems Command, "Mission Need Statement (MNS), Naval Aviation Logistics Data Analysis Program," 9 September 1997.

Naval Air Systems Command, "Operational Requirements Document, Naval Aviation Logistics Data Analysis Program," 9 September 1997.

Naval Air Systems Command, "Performance Measures, Proposed, Naval Aviation Logistics Data Analysis Program," 9 September 1997.

Naval Air Systems Command, "Program Managers Charter, Naval Aviation Logistics Data Analysis Program," 9 September 1997.

O'Brian, J. A., *Management Information Systems: A Managerial End User Perspective*, Irwin, pp. 338-375, 1993.

Russell, G. W., "Experience with Inspection in Ultralarge-Scale Developments," *IEEE Software,* vol. 8, no. 1, pp. 25-31, 1991.

Simon, H. A., *The New Science of Management Decision,* Prentice-Hall, 1977.

Snead, K. C. and Harrell, A. M., "An Application of Expectancy Theory to Explain a Manager's Intention to Use a Decision Support System," *Decision Sciences*, vol. 25, no. 4, pp. 499-513, 1994.

SPAWAR, "Total Ownership Costs Databases," http://rba.spawar.navy/mil/toc/toc.htm, June 1999.

Sprague, R. H., "A Framework for the Development of Decision Support Systems," *MIS Quarterly*, vol. 4, no. 4, pp. 49-76, 1980.

Sprague, R. H. and Watson, H. J., *Decision Support for Management*, Prentice-Hall, pp. 102-116, 1996.

The Standish Group, Chaos, http://www.standishgroup.com/chaos.html, April 1999.

The Standish Group, "Charting the Seas of Information Technology," The Standish Group, 1994.

Zawacki, R. A., "Key Issues in Human Resources Management," *Information Systems Management,* Winter, pp. 72-75, 1993

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center..2
8725 John J. Kingman Road, STE 9044
Fort Belvoir, VA 22060-6218

2. Dudley Knox Library...2
Naval Postgraduate School
411 Dyer Road
Monterey, CA 93943-5104

3. Professor Dan C. Boger, Code IS/Bo...1
Information Systems Academic Group
Naval Postgraduate School
Monterey, CA 93943-5000

4. Professor Donald Eaton, RADM, USN (Ret), Code SM/Et 1
555 Dyer Road
Monterey, CA 93943-5104

5. Professor William J. Haga, Code SM/Hg...........................1
Department of Systems Management
Naval Postgraduate School
Monterey, CA 93943-5000

6. Professor Carl R. Jones, Code SM/Js...1
Department of Systems Management
Naval Postgraduate School
Monterey, CA 93943-5000

7. Mr. John Mishler...1
Naval Air Systems Command
Code 3.6.2
Unit 8, Building 447
47060 McLeod Road
Patuxent River, MD 20670-1547

8. Mr. Doug Jahn..1
Naval Air Systems Command
Code 3.6.2
Unit 8, Building 447
47060 McLeod Road
Patuxent River, MD 20670-1547

9. Mr. Duane Bishop...1
Naval Air Systems Command
Code 3.6.2
Unit 8, Building 447
47060 McLeod Road
Patuxent River, MD 20670-1547

10. CDR Mark Krause...2
118 Thatcher Road
Slidell, LA 70461

11. LCDR Ellen Evanoff...2
1430 Augusta Place
Monterey, CA 93940